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CHEMICAL WASTE INCINERATOR SHIP PROJECT

(VOLUME I. ENVIRONMENTAL ANALYSIS AND APPENDICES I, II, AND III)

MARITIME ADMINISTRATION

1975

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UNITED STATES

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ENVIRONMENTAL IMPACT STATEMENT

MARITIME ADMINISTRATION
CHEMICAL WASTE
INCINERATOR SHIP PROJECT

VOLUME 1 of 2

MA-EIS-7302-76-08D

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The Maritime Administration is presently considering Agency support for development of a U.S. flag operated incineration at sea capability. As many as four incinerator vessels may eventually be needed nationwide. This project, called the Chemical Waste Incinerator Ship Project, is in harmony with the intent of the Marine Protection, Research and Sanctuaries Act (P.L. 92-532).

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(X) Draft Environmental Statement ( ) Final Environmental Statement

U.S. Department of Commerce
Maritime Administration
Washington, D.C.

1. Type of Action: (X) Administrative ( ) Legislative

2. Description of Action: Related to the growth of the chemical industry has been the accumulation of an ever increasing volume of toxic chemical wastes, such as chlorinated hydrocarbons. A relatively environmentally safe disposal method for toxic chemical wastes, which are liquid and combustible, is incineration at sea.

The Maritime Administration is presently considering Agency support for the development of a U.S. flag operated incineration at sea capability. As many as four incinerator vessels may eventually be needed nation-wide. This project, hereinafter called the Chemical Waste Incinerator Ship Project, is in harmony with the intent of the Marine Protection, Research and Sanctuaries Act (P.L. 92-532).

3. Description of the Marine Environment: For the purposes of this statement, the marine environment can be conveniently grouped into two major domains: the coastal ocean and the open ocean. The coastal ocean includes estuaries and adjacent wetlands, lagoons, the waters over the continental shelves, and the marginal seas. The open ocean lies seaward of the continental shelves and is not significantly affected by continental boundaries or by the ocean bottom. There is no clear-cut boundary between the coastal and open oceans, but for the purposes of this statement water deeper

than 3,000 feet will be considered solely as part of the open ocean. A third domain, that of freshwater, is also considered since chemical waste incinerator ships may transit inland waterways and lakes in order to load waste cargo.

4. Environmental Impact and Adverse Environmental Effects: Environmental impact of the proposed action would result from the construction/conversion, operation, maintenance, and repair of the vessels to be built under the Chemical Waste Incinerator Ship Project. The Project requires that the vessels be constructed or converted in shipyards of the United States. The construction, conversion, repair and scrapping of the ships will have a limited adverse effect on the local environment because of the nature of the industry. Once the vessels become operational, there will exist a potential hazard to the marine environment from the accidental release of harmful substances due to casualties and other mishaps. The extent of impact of such spills depends on the degree of pollution, type of pollutant spilled, spill location, duration of spill, and physical conditions under which the spill occurs.

The high temperature combustion in the open ocean of toxic chemical wastes, under strictly observed safety regulations, has minimal adverse impact on the marine environment. For chlorinated hydrocarbons, conversion is principally to water vapor, carbon dioxide, and hydrogen chloride. Combustion efficiencies are in excess of 99.9%.

5. Safety and Control Measures:

a. U.S. Coast Guard Design, Construction and Operating Requirements
b. American Bureau of Shipping Rules
c. International Standards
d. National Statutes and Regulations
e. Maritime Administration Specifications
f. Training

6. Alternatives Considered: Alternative methods of treatment and disposal for hazardous wastes, such as toxic chemicals, have been considered in this statement. These processes include physical treatment, chemical treatment, thermal treatment, biological treatment, and ultimate disposal. The alternative of no Project is also discussed.

7. Comments on the Draft Impact Statement are requested from the following:

- a. Environmental Protection Agency
- b. Department of State
- c. Department of the Interior
- d. U.S. Coast Guard, Department of Transportation
- e. Department of Health, Education and Welfare
- f. Department of the Army, Corps of Engineers
- g. Department of the Navy
- h. Department of the Air Force
- i. Department of Transportation
- j. States of Alabama, Alaska, California, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, North Carolina, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Virginia, Washington and Wisconsin.
- k. Environmental Defense Fund, Inc.
- l. Resources for the Future
- m. Water Pollution Control Federation
- n. American Bureau of Shipping
- o. American Eagle Foundation
- p. National Academy of Sciences
- q. National Science Foundation

8. Draft Statement made available to the Council on Environmental Quality and the public DEC 1 1975.

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* This Draft Environmental Impact Statement consists of two volumes. Volume 1 contains the Environmental Analysis and Appendices I, II, and III. Volume 2 contains Appendix IV.

CHAPTER I

DESCRIPTION OF THE CHEMICAL WASTE INCINERATOR SHIP PROJECT

A. THE NEED FOR CHEMICAL WASTE INCINERATOR SHIPS

The management of the Nation's hazardous residues - toxic chemical, biological, radioactive, flammable, and explosive wastes - is generally inadequate; the public health and welfare are unnecessarily threatened by the uncontrolled discharge of such waste materials into the environment. It is estimated that the generation of nonradioactive hazardous wastes is taking place at the rate of approximately 10 million tons (9 million metric tons) yearly. About 40 percent of these wastes by weight is inorganic material and about 60 percent is organic; about 90 percent occurs in liquid or semiliquid form. (1)

The accumulation of an ever increasing volume of toxic chemical wastes, such as chlorinated hydrocarbons, is related to the rapid growth of the chemical industry. Disposal of these chemical wastes is a constant problem. Traditional disposal methods, such as ocean dumping and land burial, are becoming increasingly intolerable from an environmental viewpoint.

An effective and relatively non-polluting alternative to the ocean dumping of liquid wastes is incineration at sea. A successful application of this method of disposal of combustible toxic wastes has been carried out for several years in Europe aboard the incinerator ship VULCANUS, a double-hulled 4,200 DWT chemical tanker equipped with two specially constructed combustion chambers. Combustion efficiencies are maintained in excess of 99.9%.

The Maritime Administration (MarAd) presently has under consideration Agency support for the development of a U.S. capability to incinerate toxic chemical wastes at sea. This capability could be federally supported in any of three ways:

- The sale of one or more small dry cargo vessels from the National Defense Reserve Fleet (NDRF) for conversion to chemical waste incinerator ships.

- The granting of government Title XI mortgage loan guarantees for construction of one or more chemical waste incinerator ships.

- The sale of one or more NDRF small dry cargo vessels with the granting of government Title XI mortgage loan guarantees for conversion to chemical waste incinerator ships.

The sale of any NDRF vessel would be to a U.S. flag ship operator under current competitive bid procedures; the conversion would take place in a U.S. shipyard. As many as four of these incinerator vessels may eventually be needed nation-wide.

The Chemical Waste Incinerator Ship Project is in harmony with the intent of the Marine Protection, Research and Sanctuaries Act of 1972 (P. L. 92-532), as amended on March 22, 1974,(P. L. 93-254) The purpose of this Act is to regulate the transportation of material from the United States for dumping into the ocean. Section 203 of the Act directs the Secretary of Commerce to offer encouragement and to render financial and other assistance to appropriate public authorities, agencies, and institutions, private agencies and institutions, and individuals for the purpose of determining means to eliminate or minimize the dumping of all materials into the ocean. The Secretary of Commerce is also directed by Section 202 (a) to consider possible alternatives to ocean dumping. Incineration at sea is not only a possible alternative to ocean dumping but also a viable, proven, relatively non-polluting disposal method for toxic chemical wastes.

1. THE NATIONAL DEFENSE RESERVE FLEET

The National Defense Reserve Fleet (NDRF), created by an Act of Congress in 1946, is maintained by the Maritime Administration, U.S. Department of Commerce, for the purpose of providing the United States with a sizable group of merchant ships capable of supporting the national security policies of the United States. As of January 1, 1975 there were four hundred and forty-eight (448) Navy and commercial vessels located at the three reserve fleet sites.

Three hundred and thirty-seven (337) vessels are military and MarAd retention vessels, and one hundred and eleven (111) are scrap candidates. From time to time, vessels are determined to be unsuited to the objectives of the reserve fleet and are declared obsolete. These vessels are then offered for sale by competitive bids to purchasers, both foreign and domestic, for non-transportation use or for scrapping.

Time and technology have changed the operating conditions and practices of most industries. The American merchant marine is no exception as it has undergone a tremendous alteration in the last ten years. Vessels are now larger, faster, more productive, and more efficient to operate. The industry has moved away from the utilization of breakbulk shipping to vessels specializing in the carriage of either containers, barges, or entire trucks with the wheels attached. This specialization was seen as a means to assure the maritime industry with a capacity to meet the changing technological innovations of the age. The industry must continue to respond to technological change if it is to remain a viable means of transportation for the future.

Utilization of obsolete NDRF hulls for conversion to special purpose vessels is but one way to diversify and expand the capabilities of the U.S. merchant marine. Numerous conversions of such hulls have already taken place, such as offshore drilling rigs, drilling support vessels, oil storage facilities, stationary seafood processing plants, and dormitories. The incorporation of special purpose and highly diversified marine platforms, like chemical waste incinerator ships and oil drilling rigs, into the U.S. merchant marine is extremely important. Such vessels are essential not only for the recovery of vital ocean resources, but also for the protection of the ocean environment.

2. THE MERCHANT MARINE ACT OF 1970

Title XI mortgage loan assistance is granted under the authority of the Merchant Marine Act. The Merchant Marine Act of 1970, which amended the 1936 Merchant Marine Act, maintained the basic framework and philosophy of the earlier Act, but made a number of changes designed to make the Maritime Administration Merchant

Marine Program more attractive to private operators. It provides for meaningful assistance to bulk carriers, including bulk liquid tankers for the first time. The mechanics of the 1936 Act were adjusted by the 1970 amendments to achieve its longstanding purpose: private construction and operation of a modern, balanced U.S. flag fleet which would meet the country's needs in both peace and war.

The provisions for assistance include construction-differential subsidy (CDS), operating-differential subsidy (ODS), and Title XI financing and loan guarantees. Construction-differential subsidy, within limits, makes up the difference between traditionally lower foreign construction costs and the cost of building the same vessel in a U.S. shipyard. Consequently, this assistance is essentially directed to American shipyards. Under the Title XI Loan Guarantee Program, the prospective owner can obtain a federal guarantee to assist in obtaining long-term financing in private capital markets. Assistance is also made available to operators of vessels in the form of operating-differential subsidies which make up part of the difference in cost between the operation of a vessel under the American flag and the operation of competing foreign-flag vessels. Other forms of assistance are also provided, such as technical support and research assistance, as well as certain tax benefits for qualified operators.

The owners or operators of the incinerator ship would not be eligible for CDS and ODS because of the requirements for such aid as defined in the 1936 Act. Title XI assistance could be awarded, however.

B. THE MARINE PROTECTION, RESEARCH, AND SANCTUARIES ACT OF 1972 (2, 3)

The Marine Protection, Research, and Sanctuaries Act (P.L. 92-532) enacted on October 23, 1972, provides for the regulation of ocean dumping, research on ocean dumping and other man-induced changes to the ocean ecosystems, and the designation, acquisition, and administration of marine sanctuaries.

Title I of the Marine Protection, Research and Sanctuaries Act provides for a regulatory scheme to control all materials transported from the United States for the purpose of dumping into ocean waters. In addition, the Act controls the dumping of material originating outside of the United States, if that dumping takes place in ocean waters subject to the jurisdiction or control of the United States. Finally, consistent with the declared policy, the Act also regulates the activities of federal departments and agencies transporting material for dumping into ocean waters, regardless of the location from which the transportation is initiated.

The first of the major areas covered is dumping in certain areas off the U.S. coast. The Act generally prohibits dumping material into the territorial sea or the contiguous zone of the United States without a federal permit. The Convention on the Territorial Sea and the Contiguous Zone, signed at Geneva in 1958, did not include an agreement on the proper breadth of a territorial sea; it did, however, set forth procedures for measuring one, by reference to a baseline which crosses the debouchments of internal waters. The Act therefore, does not regulate dumping in places like Long Island Sound or Chesapeake Bay. (Pollution of such internal waters, however, is dealt with by the Federal Water Pollution Control Act).

The prohibitions contained in Title I on dumping in the contiguous zone apply only to the extent such dumping "may affect the territorial sea or the territory of the United States". That limitation is based on a provision of the 1958 treaty which permits countries claiming narrow territorial seas to assert jurisdiction related to customs, fiscal, immigration, and sanitary measures in a strip of water called the contiguous zone, which lies seaward of the territorial sea. (Since the contiguous zone can extend no farther than twelve miles seaward of the baseline, countries claiming a territorial sea of twelve miles or more have no contiguous zone.)

Title I of the Act requires that any person, regardless of his nationality, may not depart a United States port with material intended for dumping anywhere in the world's oceans, unless he has first obtained a federal permit to do so from the Environmental Protection Agency. The Act also has a total prohibition against radiological, biological, and chemical warfare agents, or any high-level radioactive wastes. These hazardous substances may not be dumped or transported for dumping, and no permit can be issued for their disposal. In addition to being subject to all the prohibitions applicable to private shipping, government vessels are also prohibited from transporting material from a foreign port for dumping without a permit. A government vessel's ocean dumping is regulated no matter where it picks up or disposes of the material dumped.

The regulatory provisions are enforceable by fines of up to $50,000 and a year in jail for each unauthorized dump. In addition, a civil penalty of up to $50,000 may be assessed administratively for each such act. The Marine Act of 1972 contains a "citizen's suit" clause, pursuant to which any person may seek injunctive relief against an unauthorized dumper and may even recover his attorney's fees and other costs of the litigation.

The Environmental Protection Agency has permit authority with respect to everything except dredge material. (The dumping of dredge material requires a permit from the U.S. Army Corps of Engineers.) On 15 October 1973, EPA published in the Federal Register, Volume 38, No. 198, Part II, Ocean Dumping Final Regulations and Criteria. These regulations describe the procedures relating to application for, issuance of, and denial of permits for ocean dumping. Final criteria for evaluation of permit applications are also included. Five categories of permits are authorized:

1. GENERAL PERMIT is essentially a determination made by the Administrator to the effect that a class of materials is considered harmless and innocuous and is to be treated in a prescribed fashion. The determination and handling instructions are to be published formally in the Federal Register. This type of permit will be used to regulate such activities as: the dumping of galley waste and refuse from naval, merchant, and passenger vessels during routine operation; removal of wrecked vessels from navigation channels and their dumping in the ocean; and human burial at sea.

2. SPECIAL PERMIT regulates all materials not covered by the general permit and strictly regulates the disposal of such materials when it can be demonstrated beyond a reasonable doubt that the quantities, nature of wastes, and methods of disposal will not result in irreparable or irrevocable harmful effects on the marine environment. Bioassays and other tests as appropriate made by approved techniques will be required by EPA prior to the issuance of a special permit.

3. INTERIM PERMIT may be granted, even when a waste violates the criteria, but only when there is no economically feasible present alternative to the necessary disposal of the waste. In such cases, a permit may be granted, but only contingent on the development of a satisfactory implementation plan either to bring the waste into compliance with the criteria or to eliminate it from ocean dumping entirely.

4. EMERGENCY PERMIT will be issued only when there is danger to human health involved and there is no feasible alternative to ocean dumping. This type of permit requires consultation with the Department of State, since it deals with materials which may be prohibited under the International Ocean Dumping Convention.

5. RESEARCH PERMIT may be issued to study the impact of dumped materials on the environment.

6. DREDGED MATERIAL PERMIT, issued and administered by the Corps of Engineers, is specifically geared to dredge material and requires the same careful testing as for those materials addressed by the EPA Special Permit. The Administrator will designate appropriate sites and reserves the right to review and impose conditions on permits issued by the Corps of Engineers.

Anyone who wishes to dispose of waste in the ocean must make application for a permit by submitting a letter of application to the EPA Regional Administrator responsible for the port of exit to the disposal site under consideration.

As a result of a resolution by the U.N. Conference on the Human Environment, another conference was convened in London. This group drafted a Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, and adjourned 13 November 1972. The U.S. law to implement this Convention is in the form of Amendments (P.L. 93-254) to the Marine Protection, Research and Sanctuaries Act of 1972. The most significant change is to extend the coverage of the regulatory scheme to include United States vessels and aircraft transporting materials from locations outside of the United States for the purpose of dumping those materials into ocean waters.

In order to implement the U.S. obligation, the Amendments extend the permit-issuing authority under the Act to cover permits to U.S. flag vessels and aircraft transporting materials from locations outside the United States. At the same time, the law provides that where a foreign State which is a Party to the Convention is involved, a permit issued by that State to a U.S. flag vessel or aircraft will be accepted as if it were issued by the Environmental Protection Agency Administrator, provided that it does not authorize transportation which would be prohibited under U.S. law. This provision will remove any requirement for dual permits and, at the same time, will insure that U.S. vessels and aircraft are properly regulated in all respects. The requirement that the permit issued by the foreign State must be consistent with the minimum requirements of the United States legislation (in order to be recognized as the equivalent of a permit issued by the Administrator) is included to make certain that U.S. vessels and aircraft operate in accordance with national policy whether operating outside or within the United States.

Finally, in order to comply with Convention requirements without having an adverse impact on more stringent requirements in domestic legislation, the EPA Administrator is directed (in establishing or revising criteria upon which permits are based) to apply the standards and criteria binding upon the United States under the Convention, to the extent that he can do so without relaxing the requirements under the basic Act. This type of language is needed because of the slightly different provisions of the statute and the Convention. For instance, the Act prohibits the transportation for dumping of radiological, chemical, and biological warfare agents and high-level radioactive wastes. There is no provision for exceptions to this prohibition. On the other hand, Annex I to the Convention includes radiological, chemical, and biological warfare agents and high-level radioactive wastes as two of several classes of materials banned for dumping; at the same time, the Convention provides that under certain circumstances the prohibition relating to these various materials may be relaxed and permits for transportation for dumping may be issued. The Amendments make clear that the absolute ban on the listed warfare agents and high-level radioactive wastes must be followed by the Administrator. In addition, he must also prohibit the transportation for dumping of those other materials listed in Annex I of the Convention. However, consistent with Convention provisions, he may, in dealing with those additional materials, also utilize the Convention's exception procedures. In other words, the Administrator must follow the requirements in all cases except when, by so doing, he would have to disregard more stringent requirements of the domestic legislation.

The other Amendments are of a technical or conforming nature. In summary, the Ocean Dumping Treaty contains three items:

1. General prohibition of materials in Annex I, known as the "blacklist". This list contains mercury, cadmium, high-level radioactive wastes, organohalogen compounds, and others.

2. Requirement for a permit for ocean dumping of substances listed on Annex II, the "gray list."

3. Prohibition of dumping of anything not listed on Annexes I or II without a general permit. (See Section IVC)

In substance, these obligations of the treaty will be satisfied by the 1974 Amendments to the Act supplemented by the regulatory changes to be made by EPA.

Section 201 of the Act directs the Secretary of Commerce to work with the Coast Guard and to initiate a comprehensive and continuing program of monitoring and research regarding the effects of ocean dumping, and, in consultation with other agencies, to initiate a comprehensive and continuing research program with respect to possible long range effects of pollution, overfishing, and man induced changes of ocean ecosystems. A major purpose of these research and monitoring activities is clearly intended to provide scientific findings, evaluations, and conclusions that are relevant to defining use conflicts that could influence the decisions to grant or deny dumping permits. In requiring annual reports to Congress, the Act provides a convenient and timely mechanism for documenting these efforts.

Section 203 requires the Secretary of Commerce to conduct and encourage research, investigations, experiments, training, demonstrations, surveys, and studies for the purpose of determining means of minimizing or ending all dumping of materials within five years of the effective date of the Act. (The chemical waste incinerator ship project, defined herein, is in response to this Title II requirement.)

And finally, Section 302 of the Act authorizes the Secretary of Commerce to designate as marine sanctuaries those areas of the ocean waters, as far as the outer edge of the continental shelf, of other coastal waters where the tide ebbs and flows, or of the Great Lakes and their connecting waters for the purpose of preserving or restoring such areas for their conservation, recreational, ecological, or esthetic values. Prior consultation with other Federal agencies and approval of the President are required.

C. CHARACTERISTICS OF A TYPICAL CHEMICAL WASTE INCINERATOR SHIP

The following paragraphs describe the design, equipment, and operation of the Dutch flag ship VULCANUS. A U.S. flag chemical waste incinerator ship would be subject to additional requirements of the U.S. Coast Guard, the Environmental Protection Agency, and the Maritime Administration.

The M/T VULCANUS is a double-hulled tanker, i.e. double sides and double bottom, complying in construction and equipment with the latest Intergovernmental Maritime Consultative Organization (IMCO) regulations for ships carrying dangerous chemicals in bulk. Minimum clearance between the cargo tanks and the outer hull is 1.10 meters. Because of its size of over 4,700 metric tons deadweight, the vessel is able to operate in rough weather on the open sea.

Specifically, the VULCANUS is designed to deal with chlorinated hydrocarbons, waste products which are produced in considerable quantities and which are difficult and expensive to dispose of on land. By burning at sea, the otherwise harmful fumes are deposited in the oceans which can absorb them in considerable quantities without harm to marine life.

The vessel's double bottom can only be used for water ballast; the fuel oil is carried in tanks under and in the engine room. IMCO regulations forbid carriage of fuel under or next to cargo tanks. The engine room is separated from cargo tanks by double bulkheads, the pump room and generator room being situated in between.

The complete bridge housing of the vessel is situated aft and incorporated with the machinery housing. Accommodations for the crew of 15 are situated on three decks in the housing aft and include such amenities as a bar and a sauna.

The vessel is divided into 15 cargo tanks ranging in volume from 115 to 574 cubic meters. These tanks are flanked port and starboard by permanent ballast tanks, which, with the double bottom, make the VULCANUS a double hulled vessel, thus ensuring maximum protection against spillage in the event of collision, grounding, or other marine hazard. Tanks are filled from above through a manifold on deck. The vessel is not fitted with a loading pump, but arrangements can be made to have a movable pump on board. Where discharge of the tanks into the incinerators is concerned, all pipes run to an elaborate manifold situated in the pump room from where another pipe system leads to the incinerators. Generally, any tank can be connected to any incinerator. Since the incinerators are each equipped with three burners, it is theoretically possible to burn six different wastes with different flashpoints simultaneously, although in practice operations are somewhat different and less complicated.

All materials to come in contact with the wastes are of the appropriate quality; for chlorinated hydrocarbons, this is mild steel. Since the wastes may contain foreign substances of rather large dimensions, pumping is effected by specially conceived pumps capable of macerating pieces of up to 5 cm to about 2 mm, thus easing the digestion of wastes by the burners. To comply with IMCO requirements, cargo tanks can only be discharged through either incinerator, thus guaranteeing that no wastes reach the sea unprocessed.

The two combustion chambers are installed aft on the upper deck, are seated in specially installed wells, and are bolted to the lower deck and braced to the upper deck. They can be lifted out for maintenance and repair. Each incinerator has an outer diameter of 5. 5 meters, a brick lining of 35 cm, and an inner diameter of 4. 80 meters. The total height of each incinerator is 10. 45 meters. Each is equipped with three burners.

Gas or diesel oil is used to bring the chambers to the required combustion temperature, normally 1, 400°C, with a maximum of 1, 650°C. Only when the required temperature is reached will the pumps transfer waste to the combustion chambers; the flow is carefully controlled to ensure complete combustion of the chemical waste. Once the required temperatures are reached, the chambers are fed solely by the cargo; but, in the event the temperature falls too low to support combustion, the flow of waste is thermostatically stopped and fuel re-injected. The burners ensure an even distribution of combustion throughout the whole of the chamber.

The combined hourly capacity of the two chambers is in excess of 20 tons, the exact amount depending upon the constituency of the waste being consumed. To cope with such a throughput at the high temperature involved, approximately 180,000 cubic meters of air must be injected into the chambers. For this purpose, huge fans are installed under the incinerators, sucking air through ducts from next to the vessel's funnel and blowing it into the incinerators at a capacity of 90,000 cubic meters per chamber per hour.

The positioning of the chambers is so designed that fumes from the combustion process, which contain high concentrations of chloride, fall astern into the wake of the vessel, thus ensuring that the exhaust constituents are thoroughly mixed with sea water. Since combustion takes place with the vessel underway, a wide distribution over a large sea area is also obtained.

The incinerators with connected gear require a large amount of additional energy. For this purpose, two additional diesel generators providing 750 KW have been installed in the generator room.

The operation of the VULCANUS is subject to very strict governmental control. The government of the country from which the vessel sails issues a license for each combustion voyage and also nominates the areas in which the burning is carried out. In the United States, the Environmental Protection Agency issues the permit and designates the burn area. This burn area is normally at least 50 miles from the nearest coastline, preferably beyond the continental shelf, and obviously clear of normal shipping lanes. Notices of intended operation are given as a warning for other ships to keep clear.

The loading of the cargo is subject to supervision by the relevant authorities, and on return the vessel is inspected to ensure that all cargo has been disposed of in accordance with regulations. To facilitate this, a panel is installed containing meters for recording the temperature inside the incinerators, a time clock with date, control lamps showing when the burners and pumps are switched on, and advanced navigational equipment giving the vessel's exact position. This panel is photographed by an automatic camera every 15 minutes. All this gear is placed in a box, which is sealed by the authorities after switch-on and which is situated on the bridge. On return from a voyage, the film can be removed by governmental authorities. In addition, a trackplotter automatically draws the vessel's course on a map, which can also be given to the authorities together with certified copies of the log book.

As stated previously, the vessel is designed not to be able to dispose of waste other than by burning. Loading is carried out by shore pumps. The shipboard pumps are only capable of discharging the cargo from the tanks directly into the combustion chambers and not until the necessary temperature has been reached. International regulations require; however, that in the event the safety of the vessel may be threatened, there must be some means of discharging the cargo directly into the sea. This can be effected through cocks which, however, remain officially sealed under normal circumstances.

Each voyage generally involves about two weeks: two days loading, one day to travel to the combustion area, nine days actually burning the cargo, and one day to return to port. The VULCANUS normally operates out of Rotterdam, burning waste for German and Dutch companies; but there is no limitation regarding her operations provided that the requisite licensing has been obtained.

M/T "VULCANUS" - INCINERATION VESSEL
Specially designed for the incineration of chemical waste on sea

Length overall	*101.95 meters/334' 6"*
Breadth	*14.40 meters/ 45' 11"*
Draft - max.	*7.40 meters/ 24' 5"*
Deadweight	*4,768 metric tons*
GRT	*3,098.22 metric tons*
Tank capacity	*3,503 cubic meters*
Number of tanks	*15* *Ranging in size from 115 cbm to 574 cbm*
Tank coating	*No coating in tanks, pipes, pumps etc. All equipment consists exclusively of low carbon steel.*

Loading equipment	*Not available, but can be placed on board, if required.*
Hose connections	*4" / 6" / 8" diameter*
Safety equipment	*Specially designed for this task and in every respect in accordance with latest regulations of IMCO and Scheepvaart-Inspectie, The Hague.*
Waste to be processed	*Must be liquid and pumpable. May contain solid substances etc. in pieces upto 5 cm in size. Waste must not attack mild steel.*

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CHAPTER II
DESCRIPTION OF THE MARINE ENVIRONMENT

For convenience, the marine environment may be grouped into two major categories: the coastal ocean and the open ocean. The coastal ocean includes estuaries and adjacent wetlands, lagoons, waters over the continental shelves, and marginal seas. The open ocean lies seaward of the continental shelf and is not significantly affected by continental boundaries or the ocean bottom.

There is no clear-cut boundary between the coastal and open oceans; but for this statement, water deeper than 3,000 feet is considered to belong solely to the open ocean. Consideration of ocean conditions is necessary in order to make predictions of the movements and eventual fate of pollutants that may be spilled or discharged and for considering other environmental impacts arising from the operation of chemical waste incinerator ships.

A. OPEN OCEAN (1, 2)

Beyond the continental shelves, the open ocean is relatively unaffected by the continental boundaries. Over most of the open ocean, warm surface waters are separated from the cooler deep waters by what is known as the pycnocline, a rapid increase in density that more or less separates surface ocean waters from deeper waters. The deeper waters are known to move sluggishly after forming in the polar regions (primarily the Antarctic) and to return to the surface about 600 to 1,000 years later.

Away from the continents that interrupt surface water movements, ocean currents are primarily directed east-west. Only in the areas of the continental boundaries are the currents deflected to the north or south forming major boundary currents. Open ocean currents generally move surface waters at speeds of a few miles per day. In the boundary currents such as the Gulf Stream or the Kuroshio Current, the waters move at speeds of ten to a hundred miles per day.

Winds blowing across the ocean set the surface waters in motion. In the open ocean where tidal currents are relatively weak, these wind drift currents account for about 40 percent of the surface currents.

B. COASTAL OCEAN (1, 2)

The coastal ocean is the water adjacent to the shore; there the adjacent land boundary, freshwater runoff from the land, and local atmospheric conditions contribute significantly to the movement and mixing of the waters. The width of the coastal ocean varies, and its outer boundary is not well defined. It may be quite narrow along coasts where the continental shelf is narrow and where oceanic conditions and "permanent" currents come close to shore. Conversely, where the continental shelf is wide, the coastal ocean may be tens or even hundreds of miles wide. The coastal ocean does not, however, always coincide with the continental shelf. Where the shelf is very narrow, the coastal ocean may extend beyond the edge of the shelf, or where the shelf is very wide, the coastal ocean may extend out from shore for only a part of the shelf width.

Although making up only 12.5 percent of the ocean surface, coastal ocean waters are vitally important. Heavily used for waterborne commerce, coastal waters are also used for recreational fishing and boating, commercial fishing, and waste disposal. Despite these heavy and often conflicting uses, coastal waters are still the most productive part of the world ocean; an estimated 90 percent of the world's marine food resources are harvested there.

There is considerable variation in the movement of the waters near the shore. Tidal currents are often strong, generally strongest near the shore. They generally parallel the coast and may be either oscillatory or rotary in character depending on local geography.

Inshore from the point where surface waves break, a longshore current paralleling the shoreline usually develops. The current direction depends upon the angle at which waves approach the shore. For example, along a coastline oriented in a north-south direction with the ocean to the east, waves approaching the shoreline from the north east will produce a longshore current that flows southward. Longshore currents are highly variable because of their dependence on local waves.

Outside the surf zone, the local winds and salinity gradients, caused by runoff from the land, combine to dominate nontidal currents in the nearshore areas. Since waves breaking on a shoreline at any given time may have been for the most part generated by storm systems some distance away, the direction of wave-generated currents nearest the beach may be opposite to the direction of the currents seaward of the surf zone.

Along coasts having relatively large freshwater inflows to the ocean, such as the Atlantic Coast of the U.S., the salinity and generally the density of surface water increases with distance offshore. The average net (nontidal) flow in the near-shore zone will, along such coasts in the northern hemisphere, be directed such that the shore is on the right of an observer looking down current. Such longshore currents are particularly well developed along coasts lying to the right (looking seaward) of the mouths of major estuaries -- south of the entrance to the Chesapeake Bay, for example.

At any particular time, however, currents in the coastal ocean may be dominated by local winds or by density-induced effects resulting from these winds. Hence offshore winds will transport surface waters offshore, particularly if the wind is blowing at an angle to the shoreline such that an observer with his back to the wind has the shore to his left. Under these conditions warmer surface waters are transported offshore and cooler subsurface waters from offshore are brought to the surface near the shore, a process known as upwelling. The resulting density distribution produces, in the northern hemisphere, a current flowing along the coastline with the shore to the left of the current (looking down current).

When such an offshore or longshore wind ceases, the warmer surface layers move shoreward. In the presence of an onshore wind, the wind-induced currents run parallel to the shore in a zone just outside the breakers.

Little is known of the processes by which near-shore waters are renewed or mixed with open ocean waters. Where the runoff of freshwater from the land into the coastal ocean is sufficient to produce measurable salinity gradients, and where the rates of freshwater inflow can be determined, the mean residence time (or replacement time) for near-shore waters can be estimated. Such an estimate was made for the waters of the coastal ocean bordering the U.S. between Cape Hatteras and Cape Cod. Considering the salinity of the waters in this segment of the coastal ocean and the annual volume rate of flow from all rivers discharging from the adjacent coast, one obtains a mean residence time of about 1.5 years. Typical residence times range from a few months for a small estuary to several years for coastal ocean sectors.

C. GEOLOGICAL SETTING (3, 4)

The continental shelf is defined physically as the zone extending from the line of permanent immersion around a continent to the depth where there is a marked or rather deep descent toward the great depths. In 1970, the Hague Conference defined the continental shelf as:

> "...the area between the mean low water line and the change in the inclination of the ocean floor, from about one-eighth of one degree to more than three degrees, that marks the beginning of the continental slope. This occurs at various depths, usually between 130 and 200 meters; but it can occur as shallow as 50 meters and as deep as 500 meters. The continental shelf ranges in width from zero to 1500 kilometers".

Geographically, the continental shelf is a subpart of the continental margin, a zone separating the submerged part of a continent from the deep-sea bottom. The other subparts are the continental slope and the continental rise.

The continental slope is the declivity from the outer edge of the continental shelf into the great depths. There exists a great variation in the steepness of the continental slope. The depth of the continental slope varies from 1400 to 3200 meters. The base of the slope is marked by the continental rise. The rise is a gently sloping and smooth surface formed by the joining of a number of deep-sea fans.

Continental shelves can be classified into two primary types by composition - those that are underlain by sedimentary strata and those underlain by igneous and metamorphic rocks. Generally, the continental shelves are the top surfaces of long, thick prisms of sediment and sedimentary strata which are held in position by fault blocks, diapers, and reefs which act as dams. Tectonic activity that was parallel to the base of the continental slope has formed tectonic dams. Under such circumstances, crystalline rock is uplifted parallel to the continent resulting in a basin between the uplifted rock and the shore. Sediment is deposited in this basin; the uplifted crystalline rock acts as a dam to trap the sediment which, after filling the basin, will spill over resulting in the formation of a slope. The Atlantic and Pacific coasts of the U.S. are examples of such activity. Other tectonic dams include those formed by diaper structures which have resulted from the upward movement of salt from a depth of many kilometers. Salt domes are common in the western Gulf of Mexico and are the principle tectonic dams in that area. Biogenic dams are the principle agent in the eastern Gulf of Mexico and off the southeastern coast of the United States. These dams are coral reefs, many of which are still living.

Shelf areas underlain by igneous and metamorphic rocks are found on top of tectonic dams. Many of these shelves had a sediment cover that was stripped by glaciation. An example is the continental shelf off Maine where glacial erosion has removed the sedimentary rocks that once covered such dams. Most of the other continental shelves that are known to be underlain by igneous and metamorphic rocks are at higher latitudes where glacial erosion has been an effective agent of sediment removal.

D. BIOLOGICAL SETTING (4)

The offshore environment is broadly divided into the pelagic and benthic realms. The pelagic realm includes all ocean water above the bottom. Over the continental shelf, the waters constitute the neritic province. Waters over the slope and deep ocean bottom constitute the oceanic province. The biota of the pelagic division is generally subdivided into plankton and nekton. The benthic division includes the sea bottom and sub-bottom environment, and its biota is called benthos.

1. PELAGIC REALM - PLANKTON

All motile aquatic organisms, plant or animal, whose powers of locomotion are too feeble to resist the set and drift of currents are termed plankton. The plankton is divided into several different types on the basis of physiology and life history.

Phytoplankton includes the acellular (unicellular) floating plants and all floating multi-cellular plants such as Sargassum. As plants, all phytoplankters are capable of producing their own food from raw materials by photosynthesis. The ubiquitous distribution and occurrence in pelagic waters is influenced by several factors. Both the horizontal and vertical distributions of phytoplankton are dependent on: (a) population origin and life cycles, (b) supply and level of nutrients and growth factors, (c) physiological requirements and adaptability, (d) salinity and temperature, and (e) grazing pressure by herbivores (plant-eating animals). In addition, vertical distribution alone is influenced by: (a) vertical water mixing, diffusion, and water stability, and (b) depth of the light zone.

The animal plankters are called zooplankton. Zooplankton distributions and occurrences are also relatively continuous in pelagic waters. In general, they are influenced by the same factors that affect phytoplankton distribution and occurrence. Inorganic nutrients and depth of the light zone are not as immediately important to zooplankton as to phytoplankton, but these factors affect distribution and abundance in that greater availability of nutrients and light allow higher primary productivity and consequently a greater food supply for zooplankton.

2. PELAGIC REALM-NEKTON

Organisms which remain suspended in water and whose powers of locomotion are great enough to resist the set and drift of currents, being subject only to large-scale physical forces, are called nekton. Nekton for the offshore waters are represented by five major taxonomic categories - marine mammals, marine reptiles, the fishes, the cephalopod mulluscs (octopus and squid), and certain crustoceans (shrimp and swimming crabs). Individuals of this group commonly, but not always, range over broad areas, thus participating in several biotic communities. For example, shrimps have a pelagic planktonic larvae, an estuarine juvenile, and pelagic adult. However, most nekton are limited in geographic and vertical ranges by the same environmental conditions as less mobile organisms, i.e., temperature, salinity, available food, and types of bottom.

The nektonic component of the environment can be divided into strictly open water nekton and nekton which spend some portion of their lives in nearshore, estuarine, or marsh waters. Examples of the latter are shrimp, drum, croaker, menhaden, flounder, seatrout, salmon, etc. Many finfish of commercial and sportfishing importance, however, are strictly open water residents, such as red snapper, various groupers, sailfish, and marlin.

Many organisms are demersal; i.e., they have a particular habit of living on, or just above, the sea bottom. Since distribution and abundance of demersal organisms is generally regulated by sediment type and the bottom communities that supply food, these organisms can be considered to be part of the benthos.

3. BENTHIC REALM - BENTHOS

Organisms (plant or animal) which, as adults or in sessile stages of their life cycles, live on the bottom are called benthos. The benthos is characterized by the large numbers of sessile or relatively inactive animals which exhibit marked zonation in the inshore region. The organisms are generally distinct for each of the three zones of the neritic province (supratidal or suppralittoral, intertidal or littoral, and subtidal or sublittoral). Zonation is characterized more by dominant species than by distinct assemblages of numerous species.

The benthic environment is in general affected and defined by the same factors that influence the waters above the bottom. Additional factors to consider for the sea bottom alone are: (a) nature of the substrate, (b) nature of the sediment, and (c) sub-bottom temperatures, salinity, oxygen, and pH. The substrate may be hard or soft depending on the amount and nature of sedimentation and the degree of scouring by horizontal currents. Sediment type is usually described by percentages of carbonates, evaporites, sand, silt, and clay. Sub-bottom temperature, salinity, oxygen, and pH can be much different than the overlying waters, especially oxygen and pH values. The benthic environment becomes more stable at greater depths, i.e., it is less affected by physical forces such as currents, waves, and storm surges. Temperature and salinity data tend to fluctuate less and have smaller ranges of values than in shallow water areas closer to the air-sea interface.

The major subdivisions of the biota found in the benthic environment are epiflora, epifauna, infauna, and inflora. Epiflora are plants, cellular or accellular, macroscopic or microscopic, which are attached to or living on the bottom. Inflora are plants found in the interstitial spaces of the bottom substrate. The main benthic floral groups are the seagrasses and the benthic algae. The benthic algae predominantly inhabit rocky coastlines and hard bottom. The scarcity of such habitats allows seagrasses to dominate.

Benthic fauna which live on the bottom are termed epifauna. Many species are permanently attached to the bottom, a life style not found in the terrestial environment. Many of the epifauna are colonial or consist of groups of individuals incompletely separated from one another. These organisms have developed life-forms which appear more like conventional plants than animals. Other epifauna creep about on the bottom, and some are highly motile. Epifaunal range from the sessile organisms like sponges and anemones to the slower moving forms such as shrimp, lobsters, and crabs to the highly motile demersal fish such asflounder, red snapper, salmon, croaker and grouper.

Infaunal organisms, animals which live buried in unconsolidated sediments or burrows in solid substrates, play a major role in reworking the sediment. Fixed infauna are those which live in permanent burrows; burrowing infauna move about, displacing sediment as they go on by creeping or swimming between the sand grains. If they progress by displacing sediment particles, they are called megafauna (echinoderms, mulluscs, flatworms, and annelids).

E. ESTUARINE CIRCULATION (1, 2)

Most of the world's existing ports and harbors are located on estuaries. Despite their variety of shapes and sizes, estuaries commonly exhibit similar physical and biological processes. An estuary is a semi-enclosed coastal body of water that has a free connection with the open sea. Within an estuary, seawater is measurably diluted with fresh water which runs off from the land. Four types of estuaries can be distinguished: drowned river valleys, bar-built estuaries, fjord-like estuaries, and estuaries produced by tectonic processes.

Drowned river valleys are perhaps the most familiar. They occur along the U.S. Gulf and Atlantic Coasts. Because they are generally confined to coastlines with relatively wide coastal plains, these waterways have also been called coastal-plain estuaries. These estuaries are widespread throughout the world and are commonly the sites of major ports. Philadelphia on Upper Delaware Bay and London on the Thames River are two examples of such estuaries.

The basic circulation pattern for estuarine waters is as follows:

- In a typical estuary, the salinity of the water increases with depth and distance from the shoreline; in other words, the freshest waters occur near river mouths with the saltiest water occurring near the sea. There is usually a surface layer in which the vertical salinity change is small, an intermediate layer in which salinity increases rapidly with depth, and a deep layer in which the rate of salinity increase with depth is small, as in the surface layer. Vertical mixing takes place between the surface and bottom waters.

- Tidal currents, ebb tides, and floods usually dominate in estuaries. Superimposed on the tidal currents (usually oscillatory in nature) is a net circulation pattern (called the estuarine circulation) in which there is a net seaward flow of near-surface waters and a net flow from the mouth toward the head of the estuary in subsurface waters. There is also a small net flow from the deeper layers to the surface layers. The volume of water flowing toward the head of the estuary (per unit time) decreases from the mouth to the head of the estuary, since water is simultaneously being moved upwards (entrained) from the deeper layers to the surface layers. Consequently, the amount of seaward flow of surface waters increases from the land toward the mouth of the estuary.

The basic estuarine circulation pattern prevails in most of the coastal ocean where the input of freshwater from river run-off and rain exceeds the loss by evaporation from the surface. Thus, over the continental shelf, surface waters generally have a net motion seaward, while near bottom waters move generally toward the shore as well as moving along the coast.

The extensive mixing of surface and subsurface waters, combined with the estuarine circulation, supply nutrients (phosphates and nitrates) to surface waters. With a plentiful nutrient supply and abundant sunlight, the phytoplankton (minute floating plants) of coastal waters produce the food to support abundant marine life, both fin fish and shell fish. Eggs and larvae of various organisms are also abundant. In the open ocean where there is less mixing, surface waters are depleted of nutrients and annual productivity of phytoplankton is much less than in coastal waters.

In coastal areas, winds from certain directions move surface waters seaward. Subsurface waters are brought to the surface near the coast in a process known as upwelling. With the abundance of nutrients, the productivity of phytoplankton is generally high. Upwelling areas support some of the world's richest fisheries. One small area offshore from Peru and Chile normally supplies about one-fifth of the world's annual fish catch.

F. SHORES AND BEACHES (2)

The shore is a narrow strip of land bordering the ocean that is alternatively exposed or covered by waves or by the changes in water level due to the tide. Where wave action is relatively vigorous and the supply of sand (or gravel) is adequate, the shore is marked by a beach, i.e., a movable deposit of loose sand (or gravel). In more protected areas, wetlands (either marshes or swamps) border the shoreline. In those areas where the land is rising due to mountain building (tectonism) or the recent retreat of continental glaciers, the shore may be marked by a rocky coastline such as the New England coast (north of Cape Cod) or parts of the Pacific coast of the U.S. and the shores of Puget Sound.

Rocky shores are typical of steeply sloping coastal land areas where the sea acts directly on resistant rocks. In many of the areas used for deep water ports (especially fjord-like estuaries), rocky shorelines are common owing to the effects of glaciers that provided deep waters near shore needed for deep draft vessels. In such areas, marine organisms typically attach themselves to the rocks which support extensive communities of animals and plants.

Where sands and gravels are abundant, beaches form under the action of the waves. Built of loose sand or gravel, beaches build outward and retreat in response to changing wave conditions. Because beaches are of unstable substrate and contain little food, relatively few marine organisms grow in or on beaches. But they are not wholly devoid of life. On the lower parts of beaches where wave action is less vigorous, burrowing animals can usually be found. Although important for recreational purposes, beaches are not permanent homes for many types of marine orgänisms. In some areas, beaches are used by fish during their spawning activities. Nearby subtidal areas may also serve as nursery areas for juvenile fish.

G. WETLANDS (2)

Tidal channels and low lying areas around lagoons, estuaries, and behind barrier islands are covered either permanently or intermittently by seawater. These areas, known as wetlands, are most common along the Gulf and Atlantic coasts of the U.S. but also occur on the Pacific and Alaskan coasts. Because of the shallow water in the associated lagoons, sounds, and the water-logged soils of the regularly or intermittently flooded portions, wetlands have distinctive types of vegetation.

Wetlands are extensively used by wildlife such as waterfowl and aquatic mammals such as muskrats. Plants growing in wetlands are highly productive and constitute important food sources for marine organisms. The vegetated shallow water areas provide protection and act as hatching or nursery areas for many species of marine organisms important for commercial or recreational fisheries.

The shallow waters (usually less than 3 feet deep) of warmer water areas in and around wetlands commonly support extensive growths of ellgrass (Zostrea) or turtlegrass (Thalassia). Regularly flooded intertidal salt marshes are generally covered by salt-tolerant grasses. On the Atlantic and Gulf coasts the marshes are covered by saltmarsh cordgrass (Spartina) and on the Pacific coast by bulrushes (Scirpus), glasswort (Salicornia) and arrowgrass (Triglochin). In southern and eastern Florida and Puerto Rico, the wetlands are regularly flooded by the tides and are covered with low trees, red mangrove, and some black mangrove.

Animals are important constituents of marshes. Fiddler crabs and snails typically live in the higher parts of the marsh. Mussels are abundant in the lower marsh, and oysters form extensive banks along tidal creeks. Commercially important furbearing animals inhabit coastal marshes along many coasts. In Louisiana marshes, for example, trappers take nutria, muskrat, mink, racoon, and other furbearing animals. Waterfowl, manatees, and other marine mammals inhabit wetlands. Rare and endangered species are often found here as well.

H. INLAND WATERWAYS (FRESHWATER) (5)

Incinerator ships may at times enter freshwater rivers and inland waters for the purpose of loading waste cargoes. Life in freshwaters is influenced, as in the ocean environment, by water temperatures, dissolved oxygen, pH, color, turbidities, total dissolved solids, total alkalinity, nutrients and mineral composition.

In natural deep bodies of water, such as the Great Lakes of North America, three water layers eventually form during the summer. The upper layer, or epilimnion, represents the warm or less frequently circulating region of approximately uniform temperature and may vary in thickness from 10 feet or less in shallow lakes to 40 feet or more in deep ones. The middle layer, or thermocline, is the region of rapid temperature change defined by a change in temperature of 1.8°F for each 2.38 feet variance in depth. The lower layer, or hypolimnion, is the cold region of approximately uniform temperature. It is cut off from circulation with the upper water and receives no oxygen from the atmosphere during stratification.

As autumn comes, the standing body of water cools. Under the influence of wind-driven currents the epilimnion increases in thickness until the lake becomes homothermous, and again a period of complete circulation begins. During this period the lake becomes saturated, or heavily so, with atmospheric gases.

The nearshore zone of large deep lakes is the most important portion from the standpoint of man. Not only is it the zone that is most used by man (for example, as a source of water supply for domestic, industrial, and cooling water uses and as an area for fishing, boating and swimming), but it is also the most biologically productive portion. One basic reason for the natural high productivity of shallow water is the presence of a substrate within the lighted surface zone where photosynthesis can take place. Also, nutrients are continually recycled from the bottom sediments back into the water column due to vertical mixing processes.

As in the marine environment, the inshore and surface water are also occupied by all species of fish at one time or another during their life cycle. Some species, such as yellow perch and catfish, spend much of their lives in shallow waters; other species are present in the shallows only when immature or during migrations. Bottom associated organisms vary qualitatively and quantitatively with seasons of the year and from year to year in the same lake.

River environments differ from lakes in the following fundamental respects: (1) depth is small compared to lakes; (2) the water is generally confined to a relatively narrow channel; (3) the volume of water flows in one direction; (4) streams increase their length, width and depth with increasing age; and (5) eroded materials are transported downstream with no opportunity for return.

River environments exhibit all intergrades from the very swift rushing waters in narrow channels to situations which are relatively lake-like. This range of conditions is reflected in the biota, which varies from the distinctively characteristic organisms of falls and rapids to lake-like forms.

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CHAPTER III

ENVIRONMENTAL IMPACT OF THE CHEMICAL WASTE INCINERATOR SHIP PROJECT

Environmental impacts on the aquatic environment from the carriage and incineration of toxic chemical wastes could come from several sources. This section discusses the various environmental impacts that could result from the operation of a chemical waste incinerator ship, the most serious of which would be the accidental spillage of the chemical waste cargo.

A. IDENTIFICATION AND EVALUATION OF NOXIOUS AND HAZARDOUS SUBSTANCES TRANSPORTED BY WATER IN BULK

The process of examining and judging a material or event as a source of danger can be defined as hazard evaluation. (1) The rapid expansion of the chemical industry, combined with major advances in shipping technology, has created a wide spectrum of problems in developing a hazard evaluation system for bulk dangerous cargoes and assigning suitable ratings to specific commodities.

1. ENVIRONMENTAL VARIABLES

An assessment of the hazards of bulk chemical carriage upon the aquatic environment includes four basic sets of variables:

a. Variability of environmental conditions. In the event of a chemical spill, the extent of chemical dispersion will be determined by a multitude of natural, physical, and chemical conditions, including season, temperature, wind direction, currents, turbulence, existing pollution loads, water chemistry, etc. For example, the environmental impact of the loss in an estuary of a toxic chemical which is slightly soluble, but heavier than water, will be substantially determined by the conditions of wave action and/or currents. Without current or wave action, its heavier specific gravity would carry the chemical directly to the bottom where toxic effects will be imposed to the bottom dwelling organisms. On the other hand, with wave action and/or current, the same chemical would be diluted and transported from the immediate spill site. Thus bottom dwelling organisms or benthos at the immediate site would be spared toxic impacts, although the same may not be said for down current organisms.

b. Variability of biotic resources. The initial impact of a toxic chemical spill is limited to a large extent by the kinds and abundance of plants and animals present at the time and place of the spill. Subsequent impacts of the spill will similarly be limited by the kinds and abundance of organisms passing through or exposed to the chemical during its period of dissipation, dilution, dissolution, or decomposition. The distribution of biota is not random, and species generally inhabit very specific nitches within the ecosystem, e.g. clams in the tidal zone. Thus, a toxic chemical spill in a productive biological area will have greater biotic impacts than one in a less productive zone. At the same time, biotic composition and abundance at a specific spill site often vary dramatically on an annual basis due to predictable life history stages, e.g. waterfowl and shore bird nesting concentrations which exist in a particular area only a few months of the year.

c. Variability of spill rates. The net impacts of a toxic chemical spill will be determined to a great extent by the volume of chemical lost. Large losses provide the potential for extensive pollution effects; whereas, smaller losses normally have proportionately smaller impacts.

d. Varying chemical characteristics. Chemicals vary greatly in their physical and chemical characteristics and mechanisms of dispersion and toxicity. Some chemicals are not soluble in water and, thus, are not readily subject to dilution. Specific gravity and solubility are important in determining whether a spilled chemical remains in the surface water layer, reaches lower water layers or the bottom, or is mixed throughout the water column.

2. ENVIRONMENTAL HAZARD IDENTIFICATION AND EVALUATION SYSTEMS

Several hazard identification and evaluation systems have been developed. These include systems by: (a) the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) (2); (b) the Intergovernmental Maritime Consultative Organization (IMCO) (3); (c) the U.S. Coast Guard (4); and (d) the Environmental Protection Agency (5).

a. Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) (2, 6)

In November 1971 the Intergovernmental Maritime Consultative Organization (IMCO) Subcommittee on Marine Pollution in preparation for the October 1973 Conference to negotiate an International Convention for the Prevention of Pollution from Ships requested GESAMP to review available lists of noxious substances carried in bulk and consider their hazard to the environment if released accidentally or discharged deliberately into the sea during the normal operation of vessels carrying these substances. In developing hazard profiles for the selected substances, GESAMP used the following criteria:

Bioaccumulation.

Bioaccumulation occurs if an aquatic organism takes up a chemical to which it is exposed so that it contains a higher concentration of that substance than is present in the ambient water or its food. Profile ratings are:

- bioaccumulated and liable to produce a hazard to aquatic life or human health,
- not known to be significantly bioaccumulated,
- short retention of the order of one week or less,
- liable to produce tainting of seafood.

Damage to living resources.

In calculating damage to living resources, available 96 hr TLm data was used. TLm means the concentration of a substance which will, within the specified time, kill 50% of the exposed group of test organisms, often specified in parts per million. The bioassay may be conducted under static or continuous flow conditions.

Profile ratings are:

- highly toxic,
- moderately toxic,
- slightly toxic,
- practically non-toxic,
- non-hazardous,
- problem caused primarily by high oxygen demand,
- deposits liable to blanket the seafloor.

Hazards to human health

Three principal ways were considered in which injury to human health can occur from a substance polluting the seas and waterways, namely through ingestion of water containing the substance, ingestion of fish and shellfish which have accumulated the substance, and direct human contact with the substance and its vapors. The degrees of hazard are listed in terms of the median lethal dose (LD_{50}) of the substance, i.e. the dose of substance which will, within a specified period of time, kill 50% of a group of test animals to which it is administered.

Profile ratings are:

- hazardous (solution),

- slightly hazardous (solution),

- non-hazardous (solution).

Reduction of amenities.

Amenities are defined as values of the recreational use or scenic aspects of the environment. Profile ratings are:

- highly objectionable because of persistency, smell, or poisonous or irritant characteristics - beaches liable to be closed;

- moderately objectionable because of the above characteristics, but short-term effects leading to temporary interference with use of beaches;

- slightly objectionable, no interference with use of beaches;

- no problem.

In addition to hazard profiles of selected substances (Annex IV of the GESAMP report), the levels of dangerous toxic discharges which would be expected to kill most aquatic life in specified aquatic systems were estimated. These estimates are presented in Table IIIA-1. GESAMP recommended extreme caution in using these data, however, to insure that the results are not extrapolated to systems substantially different than those described in Annex V of the GESAMP report. The information contained in Table IIIA-1 clearly indicates that an accidental spill of highly toxic chemicals into a body of water, especially a shallow body of water, could possibly have serious local effects on the marine environment.

b. Intergovernmental Maritime Consultative Organization (IMCO) (3, 6)

The IMCO International Convention for the Prevention of Pollution from Ships, 1973, is subdivided into seven major categories:

- the Articles,

- five technical Annexes, and

- a series of Resolutions.

TABLE IIIA1

TOXIC DISCHARGE LEVELS WHICH WOULD BE EXPECTED TO KILL MOST AQUATIC LIFE IN SPECIFIED SYSTEMS

Toxicity Ranges (TLm)* ppm	Rivers** (1000 cfs)	Estuary**	Shallow Coastal Waters**
100 - 1000	6. 6 - 66 tons	62. 5 - 625 tons	5000 - 50000 tons
10 - 100	1320 - 13200 lbs	6. 25 - 62. 5 tons	500 - 5000 tons
1 - 10	132 - 1320 lbs	0. 62 - 6. 25 tons	50 - 500 tons
0. 1 - 1. 0	13 - 132 lbs	125 - 1250 lbs	5 - 50
0. 01 - 0. 1	1. 3 - 13 lbs	12. 5 - 125 lbs	0. 5 - 5 tons
< 0. 01	< 1. 3 lbs	< 12. 5 lbs	< 0. 5 tons

*The concentration of a substance which will, within a specified time (generally 96 hours), kill 50% of the exposed group of test organisms.

**See examples 1, 2 and 3 in Annex V of the GESAMP report (Reference 2) for assumed system and material characteristics and metric equivalents.

Annex II deals with pollution by noxious liquid substances transported in bulk other than oil, sewage and garbage. The substances to which Annex II applies have been subdivided into various categories based on the hazard ratings assigned by GESAMP. These chemicals and their hazard ratings are contained in Appendix I to this statement.

Category A	Substances which are bioaccumulated and liable to produce a hazard to aquatic life or human health; or which are highly toxic to aquatic life (as expressed by a Hazard Rating 4, defined by a TLm less than 1 ppm); and additionally certain substances which are moderately toxic to aquatic life (as expressed by a Hazard Rating 3, defined by a TLm of 1 ppm or more, but less than 10 ppm) when particular weight is given to special characteristics of the substance.
Category B	Substances which are bioaccumulated with a short retention of the order of one week or less; or which are liable to produce tainting of the sea food; or which are moderately toxic to aquatic life (as expressed by a Hazard Rating 3, defined by a TLm of 1 ppm or more, but less than 10 ppm); and additionally certain substances which are slightly toxic to aquatic life (as expressed by a Hazard Rating 2, defined by a TLm of 10 ppm or more, but less than 100 ppm) when particular weight is given to additional factors in the hazard profile or to special characteristics of the substance.
Category C	Substances which are slightly toxic to aquatic life (as expressed by a Hazard Rating 2, defined by a TLm of 10 or more, but less than 100 ppm); and additionally certain substances which are practically non-toxic to aquatic life (as expressed by a Hazard Rating 1, defined by a TLm of 100 ppm or more, but less than 1,000 ppm) when particular weight is given to additional factors in the hazard profile or to special characteristics of the substance.

Category D Substances which are practically non-toxic to aquatic life, (as expressed by a hazard rating 1, defined by a TLm of 100 ppm or more, but less than 1,000 ppm); or causing deposits blanketing the seafloor with a high biochemical oxygen demand (BOD); or highly hazardous to human health, with an LD_{50} of less than 5 mg/kg; or produce moderate reduction of amenities because of persistency, smell or poisonous or irritant characteristics, possibly interfering with use of beaches; or moderately hazardous to human health, with an LD_{50} of 5 mg/kg or more, but less than 50 mg/kg and produce slight reduction of amenities.

Other Liquid Substances (for the purposes of Regulation 4 of Annex II) Substances other than those categorized in Categories A, B, C and D above.

c. U.S. Coast Guard (4)

The National Research Council's Committee on Hazardous Materials was tasked to assist the Coast Guard in developing a hazard evaluation system for bulk dangerous cargoes and assigning suitable ratings for specific commodities. The results of the Committee's Study are summarized in the report, "Evaluation of the Hazard of Bulk Water Transportation of Industrial Chemicals - A Tentative Guide", published in 1966 and revised in 1969, 1970 and 1972. The ratings put forth represent the opinion of the Committee regarding the overall potential hazard connected with the bulk water shipment of specified industrial chemicals. The ratings reflect the hazards or absence of hazards in shipping chemicals in their present industrial grades in bulk by water. They are not intended to be used for any other purpose and are not considered valid to estimate the degree of hazard of handling these chemicals in any other manner. The hazard evaluation is based on four main classes of hazards: fire, health, water pollution, and reactivity. A brief description of the hazards follows, including a general scheme of the system as shown in Table IIIA-2. The specific hazard ratings for the chemicals are contained in Appendix II.

Fire Hazard - Chemicals are classified as having a fire hazard if properties are such that they may ignite or may spread a fire during bulk water transportation. Ratings are based principally on flash points; however, other factors may be considered and the rating raised or lowered accordingly if the chemical represents a hazard unlike the hazard of hydrocarbons. Chemicals having modified ratings include: (1) chemicals such as halogen -, nitrogen -, or sulfur - containing compounds that evolve noxious gases in burning; (2) chemicals having exceptionally high or low ignition temperatures; and (3) chemicals that ignite spontaneously on contact with air or water.

Health Hazards - Health hazards are classified as originating from (1) gases, vapors, fogs, and mists of liquids that produce eye, skin, or respiratory irritation; (2) liquids or solids that produce eye injury or skin burns upon direct contact; and (3) chemicals that produce systemic poisoning when absorbed by inhalation, skin absorption or ingestion.

Water Pollution - Water pollution ratings are intended to reflect the degree of concern that arises when these specific chemicals are for any reason spilled or dumped into waters controlled by the Coast Guard. A wide variety of problems may arise from such occurrences: water for municipal systems may be made unfit for human consumption; fish and other aquatic life may be killed; waters in streams or on beaches may be contaminated by oily, sticky, dark colored, or malodorous materials which make them unfit for recreational purposes; or noxious odors or vapors may evolve from polluted water to contaminate the atmosphere in areas nearby. The water pollution characteristics of chemicals are rated in three ways: (1) human toxicity, (2) aquatic toxicity, and (3) aesthetic effect.

Reactivity - This class of hazard arises from the susceptibility of chemicals to undergo a chemical reaction under the conditions of bulk water transportation. Three types of hazards are considered: (1) the reaction of chemicals with each other; (2) the reaction of chemicals with water; and (3) self-reaction, usually polymerization or decomposition.

TABLE IIIA2 - OUTLINE OF RATING SYSTEM[a]

Column:	I	II	III	IV
	FIRE	HEALTH		
		Vapor Irritant	Liquid or Solid Irritant	Poisons
Grade 0	No hazard	No effect	No effect	No effect
Grade 1	Closed cup Flash point above 140°F	Slight effect	Causes skin smarting	Slightly toxic
Grade 2	Flash point 100 to 140°F	Moderate irritation; temporary effect	First-degree burns, short exposure	Intermediate toxicity
Grade 3	Flash point below 100°F B.P. above 100°F	Irritating; cannot be tolerated	Second-degree burns, few minutes exposure	Moderately toxic
Grade 4	Flash point below 100°F B.P. below 100°F	Severe effect; may do permanent injury	Second-degree and third-degree burns	Severely toxic

TABLE IIIA2 - OUTLINE OF RATING SYSTEM[a] (Cont'd)

Column:	V	VI	VII
	WATER POLLUTION		
	Human Toxicity	Aquatic Toxicity	Aesthetic Effect
Grade C	Nontoxic; LD$_{50}$ 15 g/kg	Acute threshold limits above 10,000 ppm	No significant pollution; gases and odorless liquids
Grade 1	Practically non-toxic; LD$_{50}$ 5-15 g/kg	Threshold limits 1,000 to 10,000 ppm	Mild-odored light oils and soluble chemicals
Grade 2	Slightly toxic; LD$_{50}$ 0.5 to 5 g/kg	Threshold limits 100 to 1,000 ppm	Mild-odored, colorless, water insoluble oils; B.P. 150 - 450°F
Grade 3	Moderately toxic; LD$_{50}$50-500 mg/kg	Threshold limits 1 to 100 ppm	Light-colored high-boiling oils; odorous water-soluble compounds
Grade 4	Toxic chemicals; LD$_{50}$50 mg/kg	Threshold limits below 1 ppm	Heavy oils, colored or malodorous

TABLE IIIA2 - OUTLINE OF RATING SYSTEM[a] (Cont'd)

Column:	VIII	IX	X
	REACTIVITY		
	Other Chemicals	Water	Self-reaction
Grade 0	Inactive; may be attacked by Grade 4	No reaction	No reaction
Grade 1	React only with Grade 4	Mild reaction; unlikely to be hazardous	Mild self-reaction under some conditions
Grade 2	React with Grades 3 and 4	Moderate reaction	Will undergo self-reaction if contaminated; do not require stabilizer
Grade 3	React with each other and with those of Grades 2 and 4	More vigorous reaction; may be hazardous	Vigorous self- reaction; requires stabilizer
Grade 4	React with each other and all other grades	Vigorous reaction; likely to be hazardous	Self-oxidizing chemical; capable of explosion or detonation

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[a] These definitions were employed as a broad scheme in rating chemicals, but were not always followed rigidly. Ratings were shifted upward or downward to reflect other properties not shown in this brief outline.

d. Environmental Protection Agency (5)

The Environmental Protection Agency Technical Assistance Data System is a computer information service storing a broad spectrum of technical data on hazardous substances. This system currently contains data on ninety-seven relevant characteristics of hazardous substances.

The majority of chemicals listed in Appendices I & II can and do occur as hazardous chemical wastes. Disposal of combustible chemical wastes can be accomplished via incineration. Appendix III to this statement contains a list of hazardous waste constituents for which incineration is considered an acceptable waste treatment process. The information contained in Appendices I, II, & III is representative of transportation hazards and incineration treatment for various chemicals but is not all inconclusive.

3. GENERAL IMPACT EVALUATION

The following evaluation of impacts on the aquatic environment discusses the toxicity mechanisms and associated general impacts to be expected from chemical spills.

a. Behavior of chemicals in the aquatic environment

Overview - A spilled chemical, depending on its own particular physical and chemical characteristics, can undergo many transformations upon release into the aquatic environment. This is demonstrated in Figure IIIA-1, which is a simplified diagram of the available pathways.

Physical dilution and dispersion - The most significant physical influence on distribution of pollution in the aquatic environment results from water movements. Motions are common in both the sea and freshwater, ranging from those of molecular dimensions to oceanwide current systems.(8) Wind is the most effective source of energy in dispersing chemicals, since it results in turbulence and wind waves, the latter of which exhibit deep reaching subsurface orbital motions. These motions have a considerable influence in mixing and dispersion. Tidal currents are particularly important to dispersion in coastal waters, since they occur on a rhythmic daily basis. The influences of ocean currents, such as the California Current, and of inflowing freshwater rivers are also important.

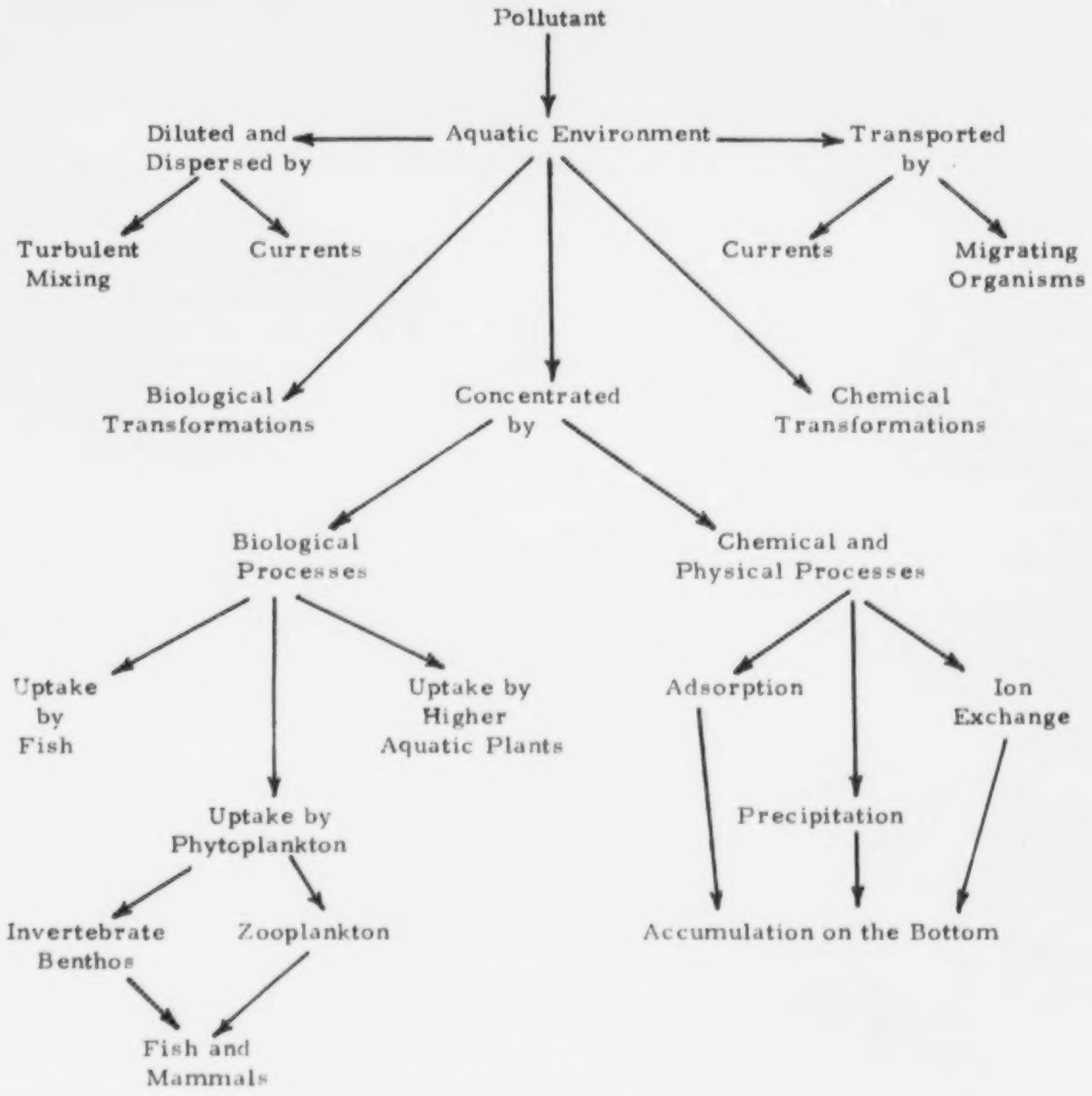
Pollutant
Aquatic Environment
Diluted and Dispersed by
Transported by
Turbulent Mixing
Currents
Currents
Migrating Organisms
Biological Transformations
Concentrated by
Chemical Transformations
Biological Processes
Chemical and Physical Processes
Uptake by Fish
Uptake by Higher Aquatic Plants
Adsorption
Ion Exchange
Uptake by Phytoplankton
Precipitation
Invertebrate Benthos
Zooplankton
Accumulation on the Bottom
Fish and Mammals

FIGURE IIIA-1 - PROCESSES WHICH INFLUENCE THE DISTRIBUTION AND FATE OF POLLUTANTS ENTERING THE AQUATIC ENVIRONMENT. (7)

Soluble substances will sooner or later be completely dissolved although the process is accelerated in the presence of water movement. Neutrally buoyant and soluble substances may remain in the water column indefinitely. Temperature and salinity influence rates of solubility and precipitation of soluble pollutants, as well as the coagulation of dispersed material.

Insoluble substances with lower density, such as mineral oil, will float on the surface and sooner or later be deposited on shore from which they may again be removed by waves, surf, or currents. If the substance is heavier than sea water, it will sink with a velocity depending on its density, shape and size. Viscosity, which depends upon temperature and salinity, will have an indirect influence by determining the sinking velocity of particles. (8)

Chemical transformations - Substances are affected in the aquatic environment by chemical transformations of either an inorganic or biological nature. Inorganic chemical transformations include radionuclide decay, oxidation-reduction, and hydrolysis. If solution parameters are known, these reactions can be predicted with reasonable certainty.

Biological reactions, including biochemical and microbial transformations, are considerably more complex. Biochemical degradation mechanisms include: dehalogenation, dealkylation, amide and ester hydrolysis, oxidation-reduction, ether fission, aromatic ring hydroxylation, and ring cleavage.

The rate, extent, and direction of microbial transformations of chemicals are commonly dependent upon the predominant flora and fauna, energy sources, available nutrients, degree of aeration, temperature, moisture, pH, light, and the presence of toxic substances. Recent studies by Jannasch and Einhjellen (9) have demonstrated that low rates of microbial activity exist under deep sea conditions. These authors concluded that deep sea waste disposal would be extremely inefficient and involve the transport of waste products of intermediate decomposition by bottom currents.

Concentration in the ecosystem - Aquatic organisms may biologically concentrate materials introduced into the aquatic environment. Buildups are achieved as uptake proceeds through the food chain from phytoplankton through fish and mammals. (7) Although a relative paucity of data exists in the area of biological concentration for most pollutants, the process is termed bioaccumulation (2) and is considered to occur if an organism takes up a chemical to which it is exposed so that it contains a higher concentration of that substance than is present in the ambient water or its food. The process is reversible and bioaccumulation may be short lived (less than 24 hours), as well as long lived. It is also recognized that metabolites may be formed from ingested substances which may be more poisonous or ecologically damaging and/or have a longer biological half life than the original material.

Pollutants are also concentrated in bottom materials, as for example when they adhere to particles of clay or other suspended material and are carried to the bottom sediments. (10) They are also occasionally concentrated in other non-living nitches as in the case of DDT in surface films of oil on the sea.

The IMCO Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) (2) has cited a number of slowly degrading chemicals, which tend to accumulate in the marine ecosystem. These chemicals include aldrin, BHC (hexachlorabenzene), heptachlor (epoxides), lead compounds, mercury compounds, and polyhalogenated biphenyls. Idler (11) provided a list of ions noted for their increasing buildup and long-term persistence in the marine environment. These include: aluminum, arsenic, beryllium, bismuth, cadmium, chromium, copper, cyanide, flouride, iron, lead, mercury, phosphorus, selenium, titanium, vanadium, and zinc.

b. Effects of Human Health

Overview - Since accidental losses of chemicals from bulk carriers always occur on or in the water, human exposure can occur either directly through body contact of the liquid, solid, or vapor state, or indirectly through ingestion via drinking water or the food chain. Human health implications of such exposure have been carefully considered and rated by GESAMP (2), the U.S. Coast Guard (4), IMCO (3), and EPA (5, 12, 13). The following four subsections concerning human health implications of noxious and hazardous substances have been abstracted primarily from the USCG tentative guide on bulk transported chemicals (4).

Chemical poisons - Poisonous chemicals gain access to the body through inhalation (e.g., chlorine, chloroform, carbon tetrachloride, oleum, oxygen difluoride and tetraethyl lead), oral ingestion (e.g., DDT, ethyl mercury and dieldrin), and skin absorption (e.g., carbon tetrachloride, acrylonitrile, and analine). Type and severity of toxic effects are dependent upon the particular chemical and its concentration in the body. Chemicals are also considered poisonous if they are anesthetics or narcotics or have a cumulative toxic effect, as well as if they are acutely toxic.

Liquid and solid irritants - Some hazardous substances will chemically "burn" or irritate human skin as a result of contact in the liquid or solid state (e.g., caustic soda, hydrochloric acid, hydrofluoric acid, nitrogen tetra oxide, and phenol). Chemicals which burn the skin are also severe in their effects on the eyes and membranes. Burns arising from heat (if in hot molten state) or cold (if in refrigerated state) can also occur.

Vapor irritants - This type of hazard involves the effect of vapors and fumes evolved from the chemical and not to splashes of the liquid itself. The class includes gases, or those chemicals which emit vapors or fogs irritating to the skin or the mucous membranes of the eyes, nose, throat, and lungs (e.g., n-butyraldehyde, carbon disulfide, cresols, diamino propane, dichloroethane, hydrocyanic acid, and hydrogen peroxide). When present in lower concentrations, many of the inhaled poisons mentioned above under Chemical poisons fit into this class.

Fire hazards - Chemicals having fire hazard are generally those with low flash points. Fire hazard chemicals can also include: (1) chemicals such as halogen-, nitrogen-, and sulfur-containing compounds which evolve noxious gases in burning; (2) chemicals having exceptionally low ignition temperatures; and (3) chemicals that ignite spontaneously on contact with air or water. Chemicals are considered a fire hazard if they may ignite or may spread a fire during bulk water transportation. Specific examples of such chemicals are hydrocyanic acid, isoprene, methane, methyl chloride, pentaborane, and petroleum ether.

c. Effects on Aquatic Organisms

Overview - For the purpose of this discussion, effects of chemical spills on aquatic organisms have been classed into two general categories: (1) direct or acute toxic effects upon organisms; and (2) sublethal effects, including chronic toxicity. An element is said to be toxic if it injures the growth or metabolism of an organism when applied above a certain concentration.(12) Definitions of direct, acute and chronic toxicity adopted for use herein are those expressed by McKee and Wolf.(14) Acute, or direct, toxicity is defined as the lethal action occurring within a period of 96 hours or less, while chronic toxicity involves deleterious effects which may not be evident for weeks, months or longer. Sublethal effects include the broad spectrum of direct and indirect effects, including chronic toxicity, which may occur in the aquatic environment as a result of chemical introduction.

Direct toxic effects - Direct toxic effects on aquatic organisms of a particular chemical have been found to vary both among species and between life stages of particular species.(15) Portmann (16) concluded, as a result of his studies of 160 "pollutants" and review of the literature, that fish larvae are more sensitive than fully grown adults with LC_{50} (the concentration required to kill 50 percent of the animals in 48 hours) values varying by a factor of 3 to 100 times. He also observed that phytoplankton species appear to be more susceptible than adult marine animals.

The most important mode of toxic action is thought to be the poisoning of enzyme systems.(12) For example, the outstanding toxicity of electronegative metals, notably copper and mercury, is related to their great affinity for amino, imino, and sulfhydryl groups, which are doubtless reactive sites on many enzymes. In view of the large number of enzymes in living cells, great variations among chemicals in toxicity to living cells are to be expected. Other modes of toxic action result from: (1) behavior of pollutants as antimetabolites; (2) formation of stable precipitates or chelates with essential metabolites; (4) combination with the cell membrane with resultant affectation of its permeability; and (5) replacement of structurally important elements in the cell with subsequent failure to function.(12)

The extent of toxic effects is also regulated by the chemical's particular physical and chemical properties as it interacts with environmental variables. For example, the toxicity of hydrogen cyanide will increase with a decrease in hydrogen ion concentration (pH), and with an increase in temperature.(12) Also, chlorinated hydrocarbon pesticides are most acutely toxic at summer rather than winter temperatures, and at least one of the common detergents becomes decidedly more toxic to fish as salinity levels increase.(12) Spill location is also important. For example, insoluble, lighter than water substances may be more persistent in colder climates, where bacterial degradation is slow. Under such conditions accumulation can occur to create a hazard to aquatic life and wild life, (e.g. seals, polar bears, and other mammals living on and under the ice).(2)

Reactions of introduced chemicals with dissolved organic and inorganic materials in receiving waters may result in neutralization, synergism, or antagonism of one substance by another. These interactions in turn determine the ultimate effects on aquatic organisms.(2, 14) The toxicity of heavy metals, which are less toxic in seawater than in fresh water, is regulated in this manner. In some instances, such as with endosulfan, the toxicity is actually higher in saline water than in fresh water.(2)

These relationships are particularly important when chemical losses occur in already polluted areas, since the lost materials will tend, in some cases, to synergize and, in others, to antagonize the effects of existing pollutants. Where synergism would occur,the net effect would generally be increased toxicity to already stressed organisms, and perhaps mortality, which might not have resulted from a spill occurring under the original non-polluted conditions. In the case of antagonistic interaction, the net effect might occasionally be beneficial, since toxic effects would be at least temporarily reduced. Predictability of synergism and antagonism is difficult since little is understood about the basic mechanisms or fundamentals governing these processes.(14).

Direct toxic effects are regulated to a large degree by the life history characteristics of organisms. In the sea, dilution of wastes is frequently very rapid so that levels which are directly toxic to fish are found only in the immediate vicinity of the point of discharge and usually persist for a relatively short period of time. (17) Most fish species have the capacity to swim away from such short term toxic concentrations, although they do not always do this, and indeed, may be attracted by certain substances (e.g., phenols). (17) Visual evidence of fish kills is generally transient, since dead and dying fish sink, are carried away by currents, or are eaten by sea birds. Lobsters, crabs, and shrimps can move away from unfavorable areas (although relatively slowly), while shellfish are not well placed to avoid pollution hazards. (17) Due to their immobility, oysters, mussels, and cockles have to cope with anything brought to them by tides, currents, or winds. These organisms have a temporary defense mechanism, being able to close their shells and exclude a poisonous substance if necessary for several hours or even days. Losses are most likely to occur in estuaries and shallow semi-enclosed coastal bays and inlets where both the volume of water and capacity of quick dilution or dispersal are limited. (17)

Sublethal effects - As used herein, the term sublethal effects is that described by Mitrovic (18) and refers to effects of all concentrations which are not necessarily lethal for individuals, even at prolonged exposures, but increase the population mortality, decrease its size or change its composition. The effect on aquatic organisms of small quantities of various toxic materials, although generally less apparent than sudden fish kills, may be even more harmful. This circumstance demonstrates why it is difficult to establish safe concentrations of toxic substances. (18) Substances most likely to cause long-term effects at low concentrations are those which are persistent in the environment and are accumulated in animals and plants or in the bottom sediments. (17) Lists of these substances have been cited by GESAMP (2), Idler (11), and USCG (4).

Sublethal concentrations of chemicals or their reactant products may affect reproduction in many different ways. Induced abnormal development of embryos may result in deformed or non-functioning larvae, which cannot survive hatching. Reproduction may be influenced by induced behavioral changes in the adults during the mating season. Their behavior, the production of eggs and sperm, the secretation of egg membranes, and the production of egg nutrients and egg shells may all be affected by change of hormone function and enzyme activity. (19) Alderson (20) found that for the larvae of plaice, Pleuronectes platessa L., on exposure to sublethal levels of chlorine, though not killing the larvae, in some way prevented the hatching mechanism from operating successfully. He also found that very low levels of chlorine would produce significant larval and egg mortalities (e.g., LD_{50} 0.024-0.34 ppm for larvae and 0.07 - 0.12 ppm for eggs). David (19) cited a study by Kinne and Rosenthal which showed that in concentrations of $FeSO_4$ and H_2SO_4 as low as 1:32,000 the percentage of successful fertilization of herring (Clupea harengus) eggs was reduced, embryonic growth rate was retarded, the embryonic heat frequency was enhanced (stress), the duration of incubation was decreased, the percentage of successful hatchings was reduced, and the occurrence of structural abnormalities in the hatchings was increased.

Nutrient containing or yielding chemicals may lead or contribute to eutrophication in some waters. This tends to be truer in enclosed water areas, particularly in the tropics. Since bacterial activity has been demonstrated to be temperature dependent it is anticipated that degradation of spilled chemicals will be most rapid in warm tropical waters and slowest in cold arctic waters. Chemicals which are readily biodegradable in temperate waters, may, due to temperature related persistence, have significant long-term consequences in the Arctic.(2) · Compounds exhibiting high biological oxygen demand (BOD) can have chronic, as well as acute, toxic effects, particularly in tropical and semi-tropical waters. (2)

Many chemicals or their reactants will find their way to the bottom. For example, colloidal clay suspensions, available from inflowing fresh water run-off, will absorb certain chemicals, including nutrients and pesticides, which in turn will reach the bottom as the clay is flocculated on mixing with seawater.(2)

Others will be deposited after reaction with plankton and other suspended organic matter. Some, such as phosphorous, tetraethyl lead, and sulfur, will sink to the bottom since they are heavier than seawater and not highly soluble.

Once at the bottom substances such as heavy metals, pesticides, and nutrients are incorporated in the sediments, where they may cause toxic effects on benthos and other organisms frequenting the water mass near the bottom. However, it does not necessarily follow that the chemical has found a final resting state, since oxidation-reduction reactions may cause them to be released or currents may transport them to other locations.

Ranchor (21) reported on the release of waste acid off Helgoland (German Bight) containing about 10% H_2SO_4, 14% $FeSO_4$ and also mineral pollutants. Bottom samples showed a loose mass of Fe (III) oxide-hydrate flakes floating above the sediment. Under laboratory conditions, this waste acid was found to have harmful effects even in great dilution. However, field studies were not so conclusive. Although faunal collections indicated a change in benthic species composition, it was considered impossible to prove any harmful effect to the macrofauna. Some macrofaunal species, originally scarce in the research area, now exist there in great numbers, making up more than 50% of the total organisms. This could be due to the natural processes, or it may have been favored by the waste disposal.

Chemicals which cause suspensoids may, on occasion, significantly reduce light penetration and, in so doing, affect the growth of bottom algae and reduce phytoplankton production. (17) Avoidance reactions to various toxic chemicals have been observed for both fish and other organisms. These reactions impact organisms in various ways. For example, Portmann (16) found that European brown shrimp (Cragon cragon) were able to detect and escape from 3.3-10 ppm of H_2SO_4 and 10-33 ppm of phenols, indicating that this species can, through avoidance, probably escape direct toxicity from spill incidents. Chemical losses may have significant impacts when they cause avoidance reactions at critical times or locations. Mitrovic (18) cited a study by Kalakiner which concluded that fish would not inhabit parts of a river with phenol content higher than 0.2 mg/l, while Ishio (22) described an imbalanced fish distribution in the Onaga River (Japan), where parts of the river were polluted by coal washing wastes containing phenol in concentrations 0.024-0.1 mg/l. Elson (23) concluded that slow upward passage of Atlantic salmon (salmo solar L.) through the Miramitchi River (Canada) appears to be attributed to the Miramitchi's burden of industrial pollution.

Some substances often accumulate in organisms or bottom sediments from which they can be taken up by bacteria and bottom living organisms. (10) Once accumulating in the food chain, they may eventually reach concentrations of harm to the involved organism life history stages. Through concentrations in parts of fish and shellfish, the substances may result in public health hazards and economic losses due to tainting problems. Substances most commonly implicated in tainting of fish and shellfish are oil, phenols and cresols. (17)

Since chemicals may be washed ashore at any point and may be deposited directly on the inter-tidal zone, the filter-feeding shellfish such as mussels and oysters are most frequently affected although lobsters and crabs may be similarly affected. Idler (11) cites a study by Nitta which concludes that bitter tastes from soft clams in a river estuary may be due to the presence of polluting metabolites of aromatic compounds.

Effects on Amenities - For the purpose of this discussion, amenities are defined as values of the recreational use or scenic aspects of the environment. (2) Reduction of amenities by polluting substances released from ships may occur as a consequence of the presence of poisonous, irritant or strong smelling substances in coastal areas used for bathing or other recreational purposes or from the occurrence on the sea surface or on the beach of objectionable scenes, slicks or other floating or suspended materials. Impairment of scenic value may also be brought about by extensive discoloration of the water or by conversion of some of the liquid substances into solids by polymerization on exposure to air and sunlight.

Sea shores and coastal waters are used by fishermen, sailors, sportmen, naturalists, and tourists in general. In harbors and enclosed waters, a spilled chemical is a direct danger when it constitutes a fire risk. It also may be a hazard to electric power generating stations, which commonly use sea water for cooling. Chemicals in the water may cause explosions in the condensers, and after a serious spill the condensers may have to be shut down. There are important indirect effects of chemical spills. For example, after the much publicized "Torrey Canyon" oil spill, fish sales in Paris dropped dramatically regardless of the origin of the fish. Amateur fishermen are more likely to experience direct effects, as they operate close in shore if not from the beach itself, seeking coastal fish with bait usually taken from the shore.

Water-oriented recreation of all kinds has become increasingly popular and costly along the coasts of affluent nations. This greatly increases the potential exposure to spilled chemicals. Some chemicals are easily transferred to boat-trailers, automobiles, recreational vehicles and clothing.

Diving, surfing and water-skiing are also sports of increasing popularity which require expensive equipment (for example neoprene-foam "wet suits") which may be ruined by contact with damaging chemicals. Many plastic and rubber-based items are ruined by contact with chemicals. The loss of seasonal income from tourists is possible as a result of some spills. Many parts of the country depend heavily on tourism. Even a single slump due to a chemical spill can have significant adverse effect on the economies of the coastal communities affected. The effects of adverse publicity can in fact last much longer than the effects of pollution.

B. POTENTIAL SOURCES OF MARINE POLLUTANTS

Marine pollution has been defined by the United Nations Conference on the Human Environment (June 1972) as the introduction by man, directly or indirectly, of substances or energy into the marine environment resulting in such deleterious effects as harm to living resources, hazards to human health, hinderance to marine activities including fishing, impairment of quality for use of sea water, and reduction of amenities. Potential sources of marine pollution from project vessels are outlined in the following paragraphs; detailed descriptions of these sources and related abatement requirements and procedures may be found in the Maritime Administration Environmental Impact Statements on the Bulk Chemical Carrier Construction Program (24) and the Tanker Construction Program (25). The discussion of incinerator exhaust emissions is contained in the next section to this chapter.

A chemical waste incinerator ship is a specialized bulk chemical carrier designed and operated to safely transport and dispose of toxic organic chemical wastes. Possible sources of pollution from the transportation mode are outlined in Figure IIIB-1 which is typical for bulk chemical carriers (24). Due to the special design and operation of the incinerator ship, e.g. it has segregated ballast and transports cargoes requiring minimum quality control, tank cleaning and ballasting operations may be considered a negligible pollutant source. The primary potential sources of chemical pollutant discharges are, therefore, transfer operations and vessel casualties.

The successful transfer of cargo to the tanker begins with the proper alignment of piping systems on board and matching of ship's manifold connections to the shore hoses. The human factor for making an error increases as the number of incompatible cargoes increases; a system of color coding is sometimes used to assist personnel in carrying out the connection of shore hoses aboard ship. There are three principal reasons for pollution during transfer operations: (1) mechanical faults, (2) design faults, and (3) human error. It is expected that spillage of chemicals during loading operations on an incinerator ship will be minimal due to the low rates of cargo transfer and the extensive safety precautions taken due to the hazards of the chemicals handled.

The potential causes of chemical pollution from a vessel casualty may be categorized as spills that result from groundings, collisions, (ship to ship casualty), rammings (ship to object casualty), fires, explosions, structural failure (including heavy weather damage), mechanical breakdowns and other casualties such as capsizing and sinking at the pier. Collisions and groundings are very likely the

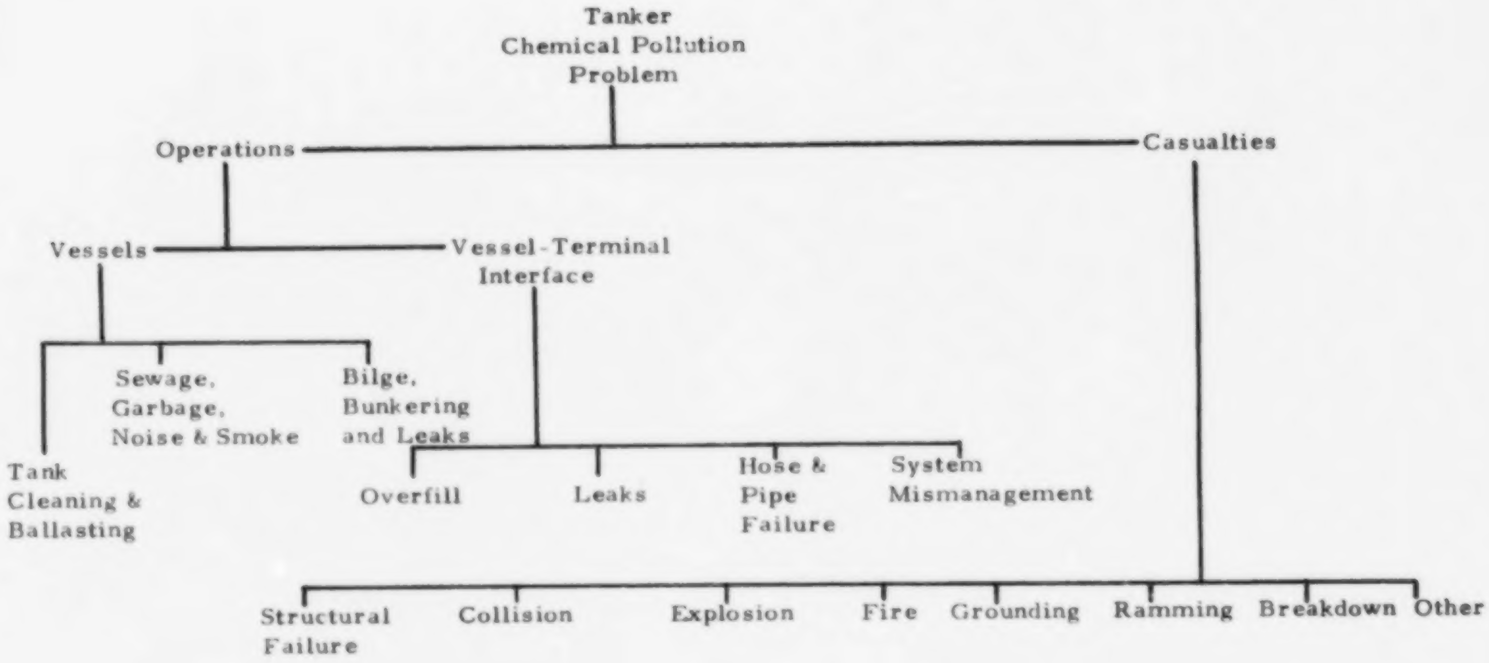
Tanker Chemical Pollution Problem
Operations
Casualties
Vessels
Vessel-Terminal Interface
Tank Cleaning & Ballasting
Sewage, Garbage, Noise & Smoke
Bilge, Bunkering and Leaks
Overfill
Leaks
Hose & Pipe Failure
System Mismanagement
Structural Failure
Collision
Explosion
Fire
Grounding
Ramming
Breakdown
Other

FIGURE IIIB-1 SOURCES OF POLLUTION FROM BULK CHEMICAL CARRIERS most serious casualty threats faced by incinerator ships. Such casualties generally result from poor navigational aids, uncharted rocks and reefs, equipment failure, bad weather, poor operational practices and errors on the part of ship crews and/or pilots. The other types of casualties tend to result from improper operations, in inadequate design, and human error. The consequences of a casualty discharge depend upon the chemical or combination of chemicals released and the design and equipment of the ship. The segregation of cargoes and the use of wing tanks and double bottom tanks should, however, minimize damage to, and thus discharge from, the cargo tanks.

Other ship generated pollutants include oil, sewage, domestic wastes, garbage, and smoke.

Oil discharges may result from bilge pumping, leaks, and bunkering operations as follows:

- Bilge pumping - The bilge is the lowest point of a ship's inner bottom and is used to collect oily wastewater from the machinery spaces. This wastewater is discharged at regular intervals.

- Leaks - Leaks occur due to lack of complete hull integrity. Welded construction and double bottoms tend to reduce leaks to a negligible quantity.

- Bunkering operations - Refueling discharges, like other transfer operations, result from (1) mechanical faults, (2) design faults, and (3) human error.

A vessel casualty could result in oil pollution as well as chemical waste pollution.

Sewage refers to human body wastes and the wastes from toilets and other receptacles intended to receive or retain body wastes. It is generated aboard ship at approximately 35 gallons/man/day. A marine sanitation device includes any equipment for installation on board a vessel which is designed to receive, retain, treat or discharge sewage and any process to treat such sewage. A polluting sewage discharge may be characterized as that which:

- results in unsightliness;
- results in noxious odors;
- causes damage to properties of the environment;
- is chemically toxic to human, animal, or plant life;
- yields pathogenic organisms;
- causes excessive oxygen depletion;
- stimulates excessive algal and water-weed growth.

Domestic wastes means wastewater from laundries, galleys, showers, sinks, etc. The most significant domestic wastes environmentally are laundry detergents and galley wastes. Domestic waste is generated aboard ship at approximately 35 gallons/man/day. Polluting discharges have many of the same characteristics as polluting sewage discharges.

All operating ships will daily dispose of garbage in various ways. Although aesthetically unpleasant, overboard discharge in the open ocean of biodegradable garbage in the amount normally produced by vessels is not considered hazardous to the environment and may in fact be beneficial to a certain extent by providing additional nutrients to an area where normal low nutrient levels may be limiting to abundant phytoplankton growth. In port, on the other hand, local ordinances usually forbid garbage being dumped overboard.

Stack emissions are usually considered in terms of: (1) smoke appearance or density; (2) quantity and size of particulate matter; and (3) quantity and noxious characteristics of gases, fumes, or vapors emitted such as sulphur oxides, nitrogen oxides, and unburned hydrocarbons. Shipboard sources of these emissions include the main steam or diesel propulsion systems, auxiliary boilers, auxiliary diesel engine driven equipment, oil-fired galley equipment, and incinerators.

C. INCINERATION DISCHARGE EFFECTS

The safe, relatively non-polluting incineration at sea of toxic chlorinated hydrocarbon wastes has been successfully carried out for two years aboard the incinerator ship, VULCANUS. Thorough monitoring and analysis of these European operations has substantiated the following argument (26):

> "High temperature combustion of chlorinated hydrocarbons, under strictly observed safety regulations, has no provable damaging influence on the water of the ocean if no more than one combustion vessel, with an hourly through put of less than 15 tons of chlorinated hydrocarbons, is operating in an ocean territory of 100 square sea miles."

The combustion process is carried-out at temperatures in excess of 1200°C, normally at 1400°C, with a residence time for the atomized waste from 0.5 to 1.5 seconds. With adequate air flows under these conditions, thermal oxidation of the organochlorines is more than 99.9% complete. Conversion is principally to water vapor, carbon dioxide (CO_2), and hydrogen chloride (HCl). Very small amounts of unburned hydrocargons also exist as may chlorine vapor and trace compounds from the waste, e.g., metals.

These gases are emitted from the incinerator stacks in a plume, which drifts downwind from the vessel, and eventually fall into the ocean.

The effectiveness of any incineration process and the characteristics of the exhaust plume are dependent upon numerous variables, some of which are: (1) waste characteristics, (2) combustion temperature, (3) residence time, (4) air supply, and (5) meteorological conditions. For example, if the organochlorines contain approximately 66% chlorine, the conversion of the majority of this chlorine to HCl results in an emission of about 498 pounds/minute of HCl at a combustion rate of 22 metric tons/hour. The distribution of the HCl behind the tanker can take a variety of forms. One extreme would be the case in which the HCl rapidly falls out into the ocean behind the tanker. This gives maximum concentrations of HCl in the water. In the other extreme, all the HCl remains in the air. This gives maximum atmospheric concentrations of HCl. The most likely case falls between these two extremes; there is an initial atmospheric dispersion, an atmospheric HCl mist may form (this depends on the ambient temperature and the relative humidity), and the HCl drifts to and is absorbed into the surface of the water.

The effects of incineration discharges can best be judged by evaluating a recent research burning operation conducted aboard the VULCANUS in the Gulf of Mexico during October 1974 through January 1975.* Four ships loads, about 4,200 metric tons each, of toxic organochlorine wastes from the Shell Chemical Company Deer Park Manufacturing

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*The first officially sanctioned ocean incineration operation in the U.S.

Complex were incinerated at a federally approved incineration site. The burns took place in an area 40 by 46 miles; the edge of the site nearest land was some 165 miles southeast of Galveston, Texas and about 190 miles south of Cameron, Louisiana. The incineration site was beyond the continental shelf, in water depths of 3,000 to 6,000 feet, outside all major shipping lanes, and well beyond commercial shrimping and fishing depths. The project was thoroughly monitored to define the environmental effects; the official Environmental Protection Agency project report, reference 28 to this chapter, is attached as Appendix IV. The environmental impacts are summarized in the following paragraphs. (27, 28)

The wastes - a mixture of chlorinated hydrocarbons with trichloropropane, trichloroethane, and dichloroethane predominating - result from the production of glycerin, vinyl chloride, epichlorohydrin, and epoxy resins. The composition of the waste feeds were similar during the two burns; both contained 63 percent chlorine, 29 percent carbon, 4 percent hydrogen, 3 percent oxygen, and traces of heavy metals. The waste feed rates averaged 21.2 metric tons/hour during the first burn and 24.5 metric tons/hour during the second burn. Combustion chamber temperatures ranged from 1340 - 1610°C. Combustion efficiencies, i.e., percentage of hydrocarbons combusted, ranged between 99.92 - 99.98%. For the most part, uncombusted hydrocarbons were not organochlorines. The efficiency of destruction of organochlorines averaged about 99.995%.

The constituents of the VULCANUS plume that might damage the marine environment were:

- HCl exhausted from the stacks in large quantities.
- Organochlorines not destroyed during incineration.
- Trace metals in the waste.

All three constituents are dissolved in the water where the stack emissions reach the ocean surface. Organochlorines and trace metals may enter the food chain and be bioaccumulated. All three constituents can have immediate impacts in the area directly affected by the plume, but may also have long-range impacts in the general area.

The oceanographic ships, OREGON II and ORCA, were used for monitoring the marine environment during the two burns. Determination of pH, chlorinity, organochlorines, and trace metals were used to detect both short-term and long-term effects; in addition, phytoplankton counts, zooplankton counts, and determination of chlorophyll-a and adenosine triphosphate (ATP) concentrations were used to assess long-term effects.

For detailed findings and conclusions refer to Appendix IV; a summary of observations follows:

1. No significant differences were detected between pH and chlorinity values of the fallout and the control areas. For example, during the first burn, in the fallout areas the pH ranged between 8.30 and 8.40; in control areas the range was 8.32 to 8.37. This observation was expected since bicarbonates naturally present in sea water neutralize the hydrogen chloride wastes.

2. Organochlorines were below detectable limits (0.5 ppb) in the fallout and control samples. This too was expected since the organochlorine wastes were so completely destroyed by the incineration.

3. No significant increases in trace metals were detected. For example, during the second burn, twelve samples were collected for analysis of copper and zinc concentrations in control areas and fallout areas. Control samples contained 0.003 - 0.005 mg/l of copper and 0.004-0.006 mg/l zinc. Test sample concentrations were 0.005 - 0.006 mg/l for copper and 0.004-0.008 mg/l for zinc.

4. No deleterious effects were observed from analysis of zooplankton, phytoplankton, chlorophyll-a, and ATP samples.

5. Stack gas emissions were monitored for oxygen, carbon monoxide, carbon dioxide, chlorine, hydrogen chloride, and unburned organochlorines. The findings indicated that more than 99.9 percent of the wastes were destroyed as required by the EPA permit. Waste feed rates did not exceed the permit limit of 25 metric tons per hour, and the flame temperatures complied with the 1350 to 1400°C average temperature requirements. (See Appendix IV for the complete permit requirements).

6. Plume dispersion characteristics were difficult to determine since the natural plume was not visible. A specially equipped EPA aircraft determined the configuration of the invisible plume by collecting emissions data at cross-sectional and longitudinal points downwind of the vessel. The natural plume trailed back from the VULCANUS stack at an angle of about 20 degrees from the horizontal, reaching a maximum altitude of 850 meters mean sea level. The plume fanned out horizontally to a width of about 1,200 meters at a distance of 2,400 meters downwind from the stack. The highest hydrogen chloride concentrations detected occurred between 100 to 240 meters altitude and zero to 400 meters downwind with a maximum value of about 3 parts per million. Ammonia was added to the gaseous emissions above the stack, and the ammonium chloride cloud generated showed a comparable configuration to that determined by the aerial monitoring of the natural plume.

7. No adverse effects on migratory birds were observed. Such birds generally migrate at altitudes of 1,000 to 5,000 feet where HCl concentrations are very low. With strong physiological drives to complete their migration, the birds would probably not linger in the incineration site.

In conclusion, the monitoring requirements imposed by EPA were appropriate in determining the impact on the marine environment, the characteristics of the plume, and the degree of waste oxidation by incineration of the Shell wastes. Results of the project indicate that at sea incineration of the Shell wastes was compatible with the intent of the Marine Protection, Research, and Sanctuaries Act, and that ocean incineration is a viable alternative to be considered along with other disposal methods, including direct ocean disposal, land disposal, and land incineration. (28)

D. SHIP CONSTRUCTION, CONVERSION, REPAIR AND SCRAPPING

1. GENERAL

In general, three functions in the ship construction industry have an effect on the environment: expansion of shipbuilding capacity; actual ship construction, alteration, repair, etc.; and the use of materials. These functions and the resultant environmental effects are described in detail in the Maritime Administration Environmental Impact Statements concerning the Tanker Construction Program (24) and the Bulk Chemical Carrier Construction Program (25) and are only summarized here.

The building via conversion or new construction of several chemical waste incinerator ships will have a minimal effect on the environment since the project is small compared to the overall ship construction program. The building of these few ships will not require expansion of presently existing facilities nor the building of new shipyards. Furthermore, all activities of the shipbuilding industry must be in compliance with applicable local, state, and federal environmental regulations.

2. POLLUTION FROM SHIP CONSTRUCTION AND CONVERSION

Ships are built in industrial areas, generally far removed from residential areas. The shipyard facilities in which the work is done include: (a) buildings which house steel panel shops and shops for processing special steel shapes; (b) machine shop, pipe shop, sheet metal shop and others in which material that goes into the hull is manufactured or otherwise processed; (c) outside storage space in which steel plates are stored; (d) outside plate or other steel assembly areas in which modules or small hull sections are assembled; (e) the shipway or building dock in which the hull is erected.

Part of the shipbuilding process is done indoors where pollution control can be effectively practiced. The work that is done outside of buildings presents greater problems in abating pollution.

In addition to the U.S. Federal regulations on pollution control in industrial activities, state and local regulations apply to areas in which shipyards are located. A status report from the Shipbuilding/Repair Industry Shipping Sub-Council of the National Industrial Pollution Control Council (NIPCC) dated September 30, 1971, advises that while tangible improvements in environmental quality in shipyards have been made, additional steps are taken as technology in pollution control are developed and as federal, state and regional regulations are formulated as guidelines in the conduct of shipyard operations.

Four principal types of pollution are identified with the shipbuilding industry: air pollution, water pollution, land pollution, and noise pollution.

a. Air Pollution

The sources of air pollution fall into three types: products of combustion, airborne particulates, and airborne fumes and vapors.

. Products of Combustion

Combustion products from ships' and yards' boilers and incinerators, smoke from burning and welding operations, exhaust from internal combustion engines and soot from boiler heating surfaces are combustion products that contribute to air pollution.

To reduce pollution from these sources, the major shipyards report only intermittent use of boilers and in some yards natural gas or low sulfur fuel is used to fire yard boilers. Use of incinerators has been discontinued in favor of having waste removed by licensed disposal firms. Smoke from burning and welding operations and internal combustion engines is generally exhausted to the atmosphere.

. Airborne Particulates

Dust resulting from abrasive blasting, dust created by woodworking machinery, and dust due to unpaved roadway surfaces contribute to pollution from airborne particulates.

The problem of airborne particulates from abrasive cleaning is the most difficult to control. The major builders have installed enclosed abrasive cleaning facilities of major size for cleaning raw stock steel and modular assemblies. The September 30, 1971 NIPCC report advised that abrasive cleaning and painting of hulls on the shipways or at outfitting berths is the subject of an intensive cooperative industry study by the Environmental Control Committee of the Shipbuilders Council of America with representation from the shipbuilding, ship repair, paint, coating and steel industries. Dust collecting systems have been installed in some of the yards for collection of woodworking dust. The yards with unpaved roadways periodically oil and water the roads.

. Airborne Fumes and Vapors

Overspray of protective coatings, evaporation of toxic chemicals and solvents, leakage of toxic or explosive gases in piping, fuel tank venting of explosive vapors, odors from sanitary facilities, and photochemically reactive hydrocarbons in paints and solvents are among shipyard airborne fumes and vapors.

The problem of overspray of painting that is done on the shipways or outfitting berths is under study along with abrasive blasting. One major builder reports approximately 75 percent of painting is done in enclosed areas where overspray is collected by media type filters. Airless spraying equipment is used as much as possible. Regularly scheduled tests are made in pipelines for toxic or explosive gases. Flame arrestors and stops are installed in fuel tank vent lines.

b. Water Pollution

The basic types of discharge that could emanate from shipyards and pollute the waterways fall into two broad categories: liquids and solids.

- **Liquids**

  Liquids include chemical make-up plus suspended solids and thermal change. Sanitary waste discharges; discharge of process chemicals; petroleum spills, overflow, and leakage; overspray and spillage of protective coatings; and discharge of cleaning fluids are among the liquids that contribute to water pollution. Sanitary waste discharges are disposed of through municipal sewer systems. Collection of process chemicals and cleaning fluids for removal by outside contractors is practiced by the major shipbuilders. Oil spill crafts with booms and other procedures are in use to handle accidental oil spills. Paint overspray and spillage have been minimized by the use of airless spray equipment and rollers.

- **Solids**

  Overboard discharge of spent abrasives, waste and scrap materials, debris from launching ways or deteriorated waterfront structures, and disposal of dredging spoils are among the solids that contribute to water pollution.

  Shipbuilders enforce strict regulations on controlling the discharge of spent materials, i.e., grit, rust, scale, and paint residues into the waterways. In the ship construction process most of the blasting is done indoors under controlled conditions. Building docks and shipways are cleaned after the blasting operation and in some of the yards abrasive material is reclaimed. One major yard disposed of abrasive materials by making land fill.

  Overboard discharge of wastes or scrap materials is against shipyard policy. Debris from launching ways is retrieved by yard water patrols. This is primarily a function of launching a ship. Disposal of dredging spoils is controlled by the Corps of Engineers through the designation of dumping sites.

c. Solid Waste and Other Pollution

Solid waste and other pollution sources include a broad variety of materials used in the various shipbuilding processes and operations. Grit, rust, scale, metal, and paint chips from abrasive cleaning of steel on shipways and outfitting berths are difficult to control. As previously noted, this problem is the subject of a cooperative industry study.

Petroleum spills from fuel handling and storage and machinery operations; metallic residues from welding and brazing operations; paint residues from coating processes; solvent spills from cleaning operations; metal scraps and particles from flamecutting operations; sand and resin dust from casting operations; and chemical spills from galvanizing all contribute to this pollution. The major shipbuilders have installed devices and methods to abate much of the pollution from these sources.

d. Noise Pollution

The major noise pollutant sources in shipbuilding have been identified as diesel and gas power source exhausts, high capacity vent fans, percussion tools and air operated tools. The industry is combating noise through the use of mufflers, silencers, equipment modifications, incorporation of noise standards in specifications for equipment and restricted use of horns and whistles.

3. USE OF MATERIALS

Ships are built primarily of steel. Steel is used in the ship's hull, machinery, piping and almost all of the other systems. In fact over 90 percent of the ship's weight is composed of steel and steel alloy. The second most important material is copper which is used in the propeller and electrical systems. The remainder of the ship uses small amounts of a large number of materials as shown on Table IIIE1.

According to the Merchant Marine Act of 1936, as amended, all material used in subsidized ships must originate in the United States, whenever practicable.

The remaining 5 to 10 percent of the material weight used represents 75 percent of the material cost of a ship. This includes manfactured items that go into a ship such as:

Main Propulsion Machinery
Shafting Propeller
Motor, Pump
Pipe, Cable
Deck Machinery

Electrical Installation
Accommodations
Ventilation
(Many others)

TABLE IIIE1 - MATERIALS USED IN SHIP CONSTRUCTION

Acetylene
Aluminum
Asbestos
Asphalt
Carbon Dioxide
Cement
Ceramics
Chemicals (acetone, alcohol, ammonia, creosote, glycerin)
Chromium
Clay
Cleaning Compounds
Copper
Cordage
Diatomaceous Earth
Fiber glass
Silicon
Steel
Tallow
Tar
Glass
Helium
Lead
Magnesium
Manganese (casting)
Mercury
Nickel
Nitrogen
Paints
Paper
Petroleum
Pharmaceuticals
Platinum
Rare Earth
Refrigerant (Chlorine, Fluorine)
Rubber
Textiles
Titanium
Wood
Wool
Zinc

The major metals to be used in shipbuilding are carbon steel, alloy steel, stainless steel, copper and copper base alloy, copper wire mill products, aluminum, and nickel alloy. The entire ship construction industry in 1971 consumed only .25 percent of the national production of carbon steel, the principal material used in ship construction.

Construction of chemical waste incinerator vessels should not materially increase steel consumption due to the relatively small size of the ships. The consumption of other material should remain relatively constant as they are more a function of the number of ships and power than of physical size.

It is estimated that labor used by material suppliers is about equal to labor used in the shipyard itself.

The analysis of material used in shipbuilding is that it is a small part of the nation's production of steel and copper products, about .50 percent. The environmental impact as far as material is concerned would be in proportion to that accorded to the steel and copper industry.

The impact on the environment of these two industries is well known. In the case of steel, open pit mining of iron ore, coal and limestone is required in addition to air and water pollution caused by the smelting process. The environmental impact caused by the manufacture of other materials is insignificant. These industries would experience no noticeable reduction in production if there were no chemical waste incinerator ship project.

5. SHIP REPAIR AND SCRAPPING

Because of casualties and routine wear and tear on vessel equipment and structures, ships spend an average of 10 days a year in a ship repair yard, during which routine maintenance and major repairs are performed. This is particularly true of U.S. flag vessels, which must, throughout their operating lives, meet Coast Guard, U.S. Public Health Service, and Federal Communications Commission regulations, in addition to classification society standards, for safe operation.

To meet this need, an extensive ship repair industry has developed in nearly every U.S. port. It includes both small, "topside" shops that only have the capabilities to repair and overhaul machinery and the topside of a ship and the ship construction yards that also have the capability to drydock vessels and repair hulls.

In essence, the potential pollutants generated by ship repair operations are the same as those created in the shipbuilding process. These fall into the following categories:

a. Air Pollution

- Combustion products, including internal combustion engine exhausts, welding and burning, and boiler operations;
- Particulates resulting from blasting and painting;
- Fumes and vapors resulting from evaporation of paint solvents, fuel tank venting, and refuse and sanitary odors.

b. **Water Pollution**

- Discharges of spent chemicals, sanitary wastes, and refuse and trash.

c. **Noise Pollution**

- Sounds of mechanical equipment in operation;
- Horns, whistles, air operated percussion tools, etc.;
- Rapid expansion of gases.

Although there are no statistics available to MarAd that indicate the volume of specific pollutants generated in the ship repair and conversion process, it is reasonable to assume that there will be few new pollutants, above those already listed. One additional waste requiring disposal could be chemical waste cargo residues which must be removed prior to ship repair.

Scrapping involves cutting the ship and its components up with torches and removing reusable equipment and parts and involves the generation of the following types of pollutants:

- Fumes and vapors resulting from the use of acetylene torches and other cutting devices;

- Unrecoverable wastes, such as lumber, insulating materials, concrete ballast, and residual chemical waste cargo;

- Sanitary wastes;

- Fuel, diesel oils, and greases.

Both ferrous and non-ferrous metals are recovered from the ship and sold to producers who recycle them. For example, the steel taken from a scrap ship is sold to a foundry which will use it in the production of new steel. Used equipment is frequently sold for reuse in its existing form.

There are no precise records of the volume of pollutants produced in the scrapping process; however, these are monitored and required to meet local and Environmental Protection Agency air and water pollution standards.

The recovery of both ferrous and non-ferrous metals during recycling results in a significant saving of natural resources and the efforts to minimize the volume of pollutants produced in the scrapping process is justified in the light of the overall savings realized.

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CHAPTER IV
SAFETY AND CONTROL MEASURES

Bulk chemical carrying ships, especially those built in the U.S. and flying the U.S. flag, are subject to extensive safety and pollution abatement regulations administered by the U.S. Coast Guard (USCG), the American Bureau of Shipping (ABS), the Environmental Protection Agency (EPA) and the Intergovernmental Maritime Consultative Organization (IMCO). These regulations were established under the authority of national legislation and international conventions. In addition, the Maritime Administration has its own requirements for safe operation and pollution control for ships built in the United States with Construction Differential Subsidy (CDS), though nothing at present directed specifically to chemical carriers.

The purpose of this Section is to present an overview of the requirements which apply to U.S. flag bulk chemical carriers.

A. U.S. COAST GUARD DESIGN, CONSTRUCTION AND OPERATING REQUIREMENTS

The U.S. Coast Guard is the primary agency responsible for the implementation and enforcement of federal merchant ship laws pertaining to maritime safety as well as those pollution abatement regulations pertaining to ship-generated pollutants. To carry out these functions, the Coast Guard maintains a specialized staff throughout the U.S. and at major overseas ports. These officials are deeply involved in all phases of ship construction and operation. Coast Guard involvement in merchant ship design begins with the submission of initial plans and specifications for approval by the Agency. Each ship is inspected initially while under construction or alteration to insure that the approved plans are being followed. Throughout the vessel's operating life, it is inspected periodically, i.e., at least every year and possibly more frequently, as conditions warrant.

Additionally, some 2,000 Coast Guard officers, enlisted men and civilian employees are responsible for the enforcement of pollution regulations. To carry out these duties, the Coast Guard operates surveillance flights in high-pollution areas, monitors transfer operations between ships and terminals, enlists the cooperation of industry and public in reporting spills and collects data on chemical cargo or oil discharges which result in new or amended regulations to combat it more effectively.

The effectiveness of the enforcement of the pollution-abatement regulations is considerably enhanced by that provision in the regulations (33 CFR 151.20) which permits Corps of Engineers employees, Bureau of Customs employees and Coast Guard officers and enlisted personnel to enforce the regulations, including the swearing out of warrants and making arrests.

Specifically, the Coast Guard enforces regulations that protect the marine environment against pollution from chemical carriers. These fall into several categories: standards for design and construction of vessels, cargo containment and fire protection requirements, navigating equipment necessary for safe operation, cargo transfer regulations and procedures for notifying proper authorities if a spill occurs.

Since most liquid bulk chemical carriers are a special form of tanker designed to safely transport hazardous bulk liquid cargoes, they must meet the construction and operating requirements of all applicable U.S. Coast Guard tank vessel regulations as well as the special requirements for the specific bulk cargoes to be carried when transporting flammable and combustible liquid cargoes in bulk. The terminology "chemical carriers" includes ships which may also carry bulk chemicals not in liquid form and petroleum products in addition to bulk chemicals. In any event, the Coast Guard requires that adequate pollution control measures for cargoes carried must be incorporated in the design of the ship, its cargo tanks, cargo transfer equipment and other protective auxiliary equipment.

The specific regulations which apply to the design, construction and operation of ships are contained in the Code of Federal Regulations (CFR), Coast Guard, Department of Transportation, Title 33, Navigation and Navigable Waters - Chapter I and Title 46, Shipping - Chapter I. Regulations which are particularly applicable to the safety and pollution abatement characteristics of bulk chemical carriers are the following:

1. TITLE 33, CHAPTER I
    - a. Subchapter C - Aids to Navigation
    - b. Subchapter K - Security of Vessels
    - c. Subchapter O - Pollution
        - Part 151 - Oil Pollution Regulations
        - Part 153 - Control of Pollution by Oil & Hazardous Substances, Discharge Removal (proposed)
        - Part 154 - Large Oil Transfer Facilities
        - Part 155 - Vessel Design and Operations
        - Part 156 - Oil Transfer Operations
    - d. Subchapter P - Marine Traffic Requirements (proposed)

2. TITLE 46, CHAPTER I
    - a. Subchapter D - Tank Vessels
        - e. g.
            - Part 32 - Special equipment, machinery & hull requirements
            - Part 34 - Firefighting equipment
            - Part 35 - Operations
            - Part 36 - Elevated temperature cargoes
            - Part 38 - Liquified flammable gases
            - Part 39 - Flammable or combustible liquids having lethal characteristics
            - Part 40 - Special construction, arrangement and other provisions for carrying certain flammable or combustible dangerous cargoes in bulk.

The Coast Guard has published a merchant marine safety manual entitled "A Manual for the Safe Handling of Inflammable and Combustible Liquids."

- b. Subchapter F - Marine Engineering
- c. Subchapter I - Cargo and Miscellaneous Vessels
    - e. g.
        - Part 98 - Special construction, arrangement and provisions for certain dangerous cargoes in bulk
- d. Subchapter J - Electrical Engineering
- e. Subchapter O - Certain Bulk Dangerous Cargoes
    - e. g.
        - Part 151 - Unmanned tank barges
        - Part 153 - Self-propelled manned vessels*
        - Part 154 - Foreign vessels

*Proposed Coast Guard regulations are in preparation for bulk dangerous chemical cargoes which are carried on self-propelled manned vessels. These regulations are based upon experience and research on the safe transportation, containment and transfer of products in barges and foreign and domestic ships. They will constitute a new Part 153 of Subchapter O. Although these regulations are not now in being as such, they do constitute the requirements upon which new U.S. vessels will be certified for the carriage of bulk dangerous chemical cargoes. Without the Coast Guard certification carriage of these cargoes would be unlawful.

For bulk chemical cargoes which are not covered by existing or proposed U.S. Coast Guard regulations, requirements will be based upon a Safety Evaluation by the Coast Guard. This evaluation is undertaken to assure that the cargo in question can be safely contained during transport, loading and unloading without pollution effects. Otherwise, Coast Guard ship design approval and cargo certification would be withheld.

The Coast Guard's design requirements for chemical carriers are intended to insure that, even if a vessel sustains damage, it will remain afloat with a minimum or no loss of cargo. To achieve this goal, the Agency prescribes acceptable levels of compartmentation and freeboard for each vessel design, so that damage to one tank, or certain combinations of tanks, will not result in the vessel's sinking.

All ships of 100 or more gross tons operating in the navigable waters and contiguous zone of the U.S. must have the capacity to retain onboard all oily wastes and oily bilge water in tanks that meet Coast Guard requirements for separation between cargo oil and bilge systems.

Since fire is one of the greatest dangers encountered aboard ship, the Coast Guard prescribes numerous detailed regulations designed to (1) prevent its occurrence, (2) limit its spread, and (3) provide effective methods of fighting it. The regulations first provide that the galleys, living quarters, navigation spaces and boiler rooms (among other compartments) be separated from the cargo tanks by cofferdams, pump rooms or tanks carrying comparatively less flammable substances. In this way, primary emphasis is placed on vessel structure as a means of preventing and containing fires. Additionally, U.S. flag ships are to be equipped in most cases, with two main fire pumping systems, located in different parts of the ship, so that one fire will not incapacitate both systems. All vessels are required to have fixed international fire main connections on board to permit the ship's fire-fighting systems to be connected with shoreside systems. All bulk chemical tank ships are required to have deck foam systems onboard and/or other specialized fire fighting systems suitable for the control and extinguishment of fires of the specific chemical cargoes carried. Finally, inert gas systems are required of large tank vessels.

Coast Guard regulations also provide that all U.S. ships must have onboard the appliances necessary to navigate safely. These include fog signal devices, navigation lights, whistles, depth indicators, radiotelegraph, radiotelephone and radio direction finders.

The regulations governing cargo handling specify the men required to be on duty, proper connections required for hoses, the strength and other characteristics of hoses, a safety inspection aboard the ship prior to commencing cargo operations and the maintenance of cargo handling equipment.

Special control measures designed for the chemical cargoes carried will be required, e.g. built-in containers on enclosed deck spaces surrounding manifolds and transfer areas to collect and contain any chemical leakage resulting from loading operations.

Many bulk chemical cargoes, characterized by their high toxicity, high energy content and/or high reactivity are considered dangerous cargoes. However, regardless of their potentially hazardous physical, chemical or toxic characteristics, these materials have been and can continue to be shipped safely when the hazards are recognized and provisions are made for their control. The procedures and rules used by the Coast Guard in regulating the shipment of bulk cargoes are intended to help accomplish reasonable safety.

The U.S. Coast Guard development of procedures and regulations for the safe water transportation of dangerous cargoes is oriented toward changing conditions in water transportation and provides for the growing size of new multiple-hazards cargoes, advances in cargo technology and increasing waterway and port congestion. The Coast Guard's approach to regulations for dangerous cargoes is predominantly casualty-preventive. It is based on achieving marine safety by evaluating potential hazards and adopting necessary preventive measures before-hand rather than investigating "after the casualty" to determine what and who is to blame. Regulations implement control of engineering design and operational procedures with respect to cargo containment, personnel and cargo transfer in order to protect against hazards which relate to the vessel, crew, public safety and environmental pollution. The regulations are designed to provide the most reasonable public and industrial safety for each cargo. The problems and experiences of industry and government as well as specific research programs serve to form the basis for appropriate safety designs and procedures.

When shipment of a dangerous cargo is planned, the shipper or carrier may contact the local Office in Charge - Marine Inspection (OCMI), U.S. Coast Guard, for assistance regarding Coast Guard rules and regulations. The OCMI will help to ascertain what Coast Guard controls exist for the cargo. He will either provide published regulations which cover the material or help determine the nature and extent of Coast Guard approval necessary. Normally, for cargoes not individually covered, he will assist by indicating the Coast Guard office which will provide the criteria or type of information upon which approval is based. For new bulk waterborne products, he may refer consideration to an appropriate contact at the Cargo and Hazardous Materials Division at Coast Guard Headquarters in Washington, D.C. There, Coast Guard personnel will review the proposed carriage and discuss approval thereof, if such is necessary. Such consideration takes place during a time period well before the planned shipment.

If shipment of a new cargo shows a continuing increasing trend, requirements for the cargo may be developed which will take the form of proposed formal regulations. These are normally submitted to industry and to a public hearing of the Marine Safety Council, U.S. Coast Guard, before being published. All pertinent comments are thus considered before regulations are promulgated. Under emergency conditions, the law permits public hearings to be waived. Changes in existing regulations are handled in the same way.

The laws which form the authority for Coast Guard regulations relating to specific chemical cargoes are contained in

- The Dangerous Cargo Act
- The Tanker Act
- The Espionage Act
- The Ports and Waterways Safety Act

The Dangerous Cargo Act provides for Coast Guard regulation of all waterborne bulk dangerous cargoes other than bulk flammable or combustible liquids. Examples of bulk cargoes regulated under this Act are ammonia, chlorine, sulfuric acid, hydrochloric acid and molten phosphorus.

The Tanker Act assigns responsibility to the Coast Guard for regulating the bulk water transportation of flammable and combustible liquids. As the name indicates, the Act applies particularly to tank vessels. Unlike the Dangerous Cargo Act, commodities are classfied in the implementing regulations primarily on the basis of flash point and Reid vapor pressure. This is a very logical and effective approach for petroleum distillates which have "conventional" fire and explosion as the primary hazards.

Requirements for the carriage of individual commodities are keyed to these classifications. However, for those bulk cargoes which have unusual stability hazards or hazardous properties in addition to flammability, additional requirements are prescribed.

The Espionage Act and Executive Order 10173, as amended, assign responsibilities for port security to the U.S. Coast Guard. Although the name implies concern only with subversive activities of an enemy, the scope of responsibility includes regulations of designated waterfront facilities which may jeopardize normal functioning of a U.S. port. In accordance with this Act, the Coast Guard administers regulations covering: (1) the handling of dangerous cargoes on waterfront facilities and onboard vessels and (2) vessel movements, as necessary, to assure the safety of ports, vessels and waterfront facilities.

The Ports and Waterways Safety Act provides for the Coast Guard implementation of regulations to promote the safety of ports, harbors, waterfront areas and navigable waters of the United States. Title I of this Act provides for ports and waterways safety and environmental quality. Title II thereof provides for Coast Guard regulation of "vessels carrying certain cargoes in bulk" operating in the ports or navigable waterways of the United States. Included in the cargoes for vessels covered by Title II are bulk cargoes which are: (1) inflammable or combustible, (2) oil of any kind (including oil mixtures) and (3) designated as hazardous polluting substances under sections 12 and 311 of the Federal Water Pollution Control Act Amendments of 1970 and 1972, respectively. All vessels operating in the navigable waterways must be certificated by the Coast Guard to carry the specific cargo or cargoes involved.

Regulations which implement the statutes just described, appear in the Code of Federal Regulations.

The National Academy of Sciences, under Coast Guard sponsorship since 1965, has been engaged in toxicological and other studies relating to water shipments of dangerous cargoes. (See Section IIIA). However, for new chemical cargoes being proposed for water transportation, the Coast Guard seeks additional information which may be developed by people who handle and use these materials in research facilities and processing plants. Service data on tank or service line ruptures, system leaks, materials compatibility, and other experiences in the chemical industry help provide solutions to related problems on vessels and during cargo transfer operations.

Pollution free and safe bulk water transportation, aside from the concept of having protective emergency equipment available, relates directly to the prevention of hazardous cargo release. The requirements for cargo containment depend upon the physical, chemical and toxic properties of the cargo. Because of the many possible varying combinations of these properties for different products, a standard procedure cannot be used to determine the design factors of a given cargo system. The approach must be on a case-by-case basis. To illustrate an extreme example, products which exhibit all the following characteristics will require the most exacting containment:

- Highly toxic
- Water insoluble
- Lighter than water
- Highly reactive
- High vapor density
- High freezing point
- Low boiling point
- Highly flammable (wide flammability range)
- Pyrophoric

Information on these characteristics is always considered in the Coast Guard's safety evaluation of cargo system design.

Loss or leakage of cargo can occur because of swamping, collision or sinking of vessels, poor design and construction techniques, and improper operation of maintenance procedures. The cargo could reach and react with or adversely affect the vessel's hull structure, contaminate the voids around the tank, pollute the air and the water, and endanger the crew (if any) and the public. The last listed is not of the least concern. Our waterways and navigable waters may traverse populated communities as well as isolated surroundings and can affect large populations.

The nature of problems encountered in water transport may be illustrated by describing typical approaches designed to protect the integrity of the vessel, the tanks, and the auxiliary equipment which are reflected in Coast Guard Regulations and Requirements.

1. VESSEL

Coast Guard regulations help minimize the possibility of sinking and the effect of collision and swamping on cargo loss by requiring the protection appropriate to the cargo hazard be built into the vessel hull. For example, for cargoes which may endanger communities and the environment, the risk associated with sinking or hull rupture may be minimized by providing:

a. varying degrees of subdivision and stability, as may be obtained by the use of double bottoms, watertight divisional bulkheads and increased reserve buoyancy;

b. collision protection for the cargo tanks, piping and equipment;

c. allowances for localized loading and longitudinal bending stresses.

This is normally considered for new vessels. If a change is required to accommodate a cargo denser than that for which the vessel was designed, the vessel strength must be reevaluated.

2. CARGO TANK

To help prevent harmful escape of cargo from the tank, the Coast Guard requires the ship designer to tailor ship structures, tanks and appurtenances to meet the needs of each specific cargo, as, for example, to:

a. Use tanks which are independent of the hull whenever feasible. Independent tanks are susceptible to a more precise design analysis and their use results in a better isolation of the tank from indeterminable hull stresses.

b. Avoid brittle fracture of the tank and nearby vessel structures through adequate materials selection.

c. Use safe outages or filling densities to help prevent the loss of cargoes with high coefficients of liquid expansion.

d. Use non-reactive tank materials, protective linings or cladding to protect against corrosion of tank structures and appurtenances in contact with reactive cargoes.

e. Apply a knowledge of cargo reaction compatibility and the effects of contamination when alternate cargoes are carried in the same tank to help prevent violent reactions.

f. Gas free and clean the tanks when cargoes are changed and check the adequacy of the tank, its saddle supports and its relief devices for any increase in specific gravity and/or vapor pressure.

g. Provide a sufficient capability to maintain necessary cargo temperatures and pressures during the transport time period plus a reasonable safety factor.

h. Note design openings in tanks below deck for volatile, explosive and toxic cargoes. This will prevent cargo liquid and vapor from seeping into confined vessel spaces with hazardous consequences.

3. AUXILIARY EQUIPMENT

Auxiliary equipment aboard dangerous cargo vessels includes that which relates to controlled heating, cooling, pressurization, pumping and venting, any one or all of which can be critical in cargo containment. Typically, hazardous situations which involve auxiliary equipment are avoided:

a. By preventing leakage:

- Physically support and protect the equipment against damage. Make sure that the equipment, itself, is structurally capable of containing the cargo and chemically compatible with it.
- Maintain absolute control of cargo transfer flow. For example, make sure that shut-off valves for hazardous cargoes are conveniently located above the weather deck or can be operated from this location, and when appropriate, use excess flow valves or suitable fail safe devices.
- Test cargo hose periodically over a period based upon test data and experience with the cargo involved.

b. By helping to reduce the possibility of fire and explosion:

- Use adequate electrical explosion-proof devices, inert gas purge systems and intrinsically safe equipment as auxiliary equipment when appropriate to the cargo hazard and location on the vessel.
- Use forced ventilation for confined vessel spaces containing cargo pumps and similar equipment.

- Use an alarm to warn of temperature malfunction.

- Provide a standby compressor for refrigeration.

- Use a system design for heating which will assure against clogging of valves, lines and openings in the vent and piping systems.

- Where cargoes are unstable under pressure, do not use cooling systems which require compression of the cargo.

- For manned vessels, use fire fighting equipment and systems appropriate to the cargo.

c. By helping to prevent chemical reactions:

- Adequately segregate cargoes which react with one another. The adequacy of segregation depends on the extent of reactivity.

- Use water-tight seals around the domes or trunks of tanks containing water-reactive cargoes.

- Maintain a reserve supply of additional inert gas padding in case of an emergency for unstable cargoes which are inert gas padded.

- Make sure the padding is free of impurities which will react with the cargo.

- Use local and remote system control for automatic sprinklers or other fire extinguisher systems employed during cargo transfer.

d. By helping to minimize the possibility of toxic exposure:

- Transport toxic cargoes under positive pressure containment. How much to contain the cargo depends upon its toxicity and other properties.

- Isolate toxic cargo tanks by voids for below-deck installations.
- Design vent heights to provide proper dilution to toxic materials in the wind, well away from personnel aboard ship.
- Use authorized qualified personnel for cargo transfer operations.

Coast Guard regulations reflect recognition that health, reactivity, fire and explosion hazards have an important influence on the design of vessels, tanks and associated equipment used in the transportation of chemicals. Regulations require that materials in contact with bulk liquids must be compatible with the liquid being transported. Corrosion, chemical reactivity and cryogenic effects which reduce structural integrity and/or enhance hazardous product formation must be avoided. Piping, venting, valving and filling arrangements must minimize exposure of personnel to toxic vapors. Electric, fire protection, cargo handling, pumping, ventilation, heat transfer and gauging systems must be appropriate to the cargo hazards for the protection of both the carrier personnel and the public. Where multiple cargoes are transported aboard the same carrier, compatibility hazards must be avoided or adequate provision must be made for them. The time use of authoritative product and equipment data is essential as well as research on new chemical situations is employed by the Coast Guard in the development of requirements to assure the safe and pollution free water transportation of chemical bulk cargoes.

B. AMERICAN BUREAU OF SHIPPING RULES

The Rules of the American Bureau of Shipping (ABS) prescribe standards for the design and construction of the hull structure, main propulsion machinery, and vital auxiliary equipment for all types of merchant vessels. Where there is sufficient need, specific rules are developed for specialized vessels, such as dry and liquid bulk cargo carriers, ore carriers, etc. Most of the basic requirements will also apply to bulk chemical carriers. Rules have been published for river barges carrying dangerous chemicals in bulk, for example. The Rules require that Surveyors to the Bureau review the design for compliance with the technical standards of the Rules, supervise the construction of the vessel and its vital machinery to insure satisfactory workmanship, ans survey the vessel periodically while it is in service to confirm that it is maintained in satisfactory condition. Both the United States Coast Guard and the Maritime Administration participate in the formulation of the Bureau's Rules.

The Bureau has been delegated the authority by the U.S. Coast Guard to assign load lines in accordance with the International Load Line Convention. In some areas, ABS standards and/or inspection are accepted as evidence that Coast Guard regulations are met, but ABS is not empowered to regulate on behalf of the U.S. Coast Guard.

C. INTERNATIONAL STANDARDS

The need for international agreement on measures curbing the growing volume of pollution from ships is reflected in various agreements reached over the last several decades. Foremost among these are the conventions and standards developed and adopted by the Intergovernmental Maritime Consultative Organization (IMCO). IMCO is a specialized agency of the United Nations whose purpose is to achieve the highest practicable standards of maritime safety and efficient navigation by facilitating cooperation among governments in technical maritime matters of all kinds of shipping. The IMCO Marine Environment Protection Committee and Maritime Safety Committee are primarily concerned with the abatement of marine pollution and with maritime safety.

1. IMCO CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING DANGEROUS CHEMICALS IN BULK (1, 2)

This Code, developed by the IMCO Subcommittee on Ship Design and Equipment of the Maritime Safety Committee, is based upon a philosophy of relating cargo containment features of vessel design, construction and operation to the hazards of the various chemicals covered by the Code. The solution is understood by examining highlights of the basic elements of the Code.

a. Chapter I - General

Chapter I, among other things, presents the scope of the Code with respect to the products covered. The Code applies to bulk cargoes of dangerous chemical substances other than petroleum or similar flammable products as follows:

. products having significant fire hazards in excess of petroleum and similar flammable products, and

. products having significant hazards in addition to or other than flammability.

The U.S. Coast Guard's Hazard Evaluation System is used as a guide for determining which products come within the scope of the Code.

Principally, only products with high ratings, i. e., three or four in the hazard evaluation system, are included in the Code. See Section IIIA of this document. Additional hazard evaluation systems, e. g., those of Norway and the United Kingdom, are also used. Further, this Code is limited to those products which are liquids at normal temperatures. Requirements for the bulk transport of liquefied gases will be contained in the IMCO Gas Code. Chapter I also provides the phased time periods for existing ships to come into compliance with the Code.

Hazards of chemicals, as considered by the Code, are as follows:

- Fire hazard defined by flash point, boiling point, explosion limit range and auto-ignition temperature of the chemical.
- Health hazard defined by:
  - (i) irritant or toxic effect on the skin or to the mucous membranes of the eyes, nose, throat and lungs in the gas or vapor state combined with vapor pressure; or
  - (ii) irritational effects on the skin in the liquid state; or
  - (iii) toxic effect via skin absorption, taking into account LC_{50} (inhalation), LD_{50} (skin) and LD_{50} (oral).
- Water pollution hazard defined by human toxicity, water solubility, volatility, odor or taste and specific gravity.
- Air pollution hazard defined by:
  - (i) Emergency Exposure Limit or LC_{50};
  - (ii) Vapor pressure;
  - (iii) Solubility in water;
  - (iv) Specific gravity of liquid;
  - (v) Relative density of vapor.

- **Reactivity hazard** defined by reactivity with:

  (i) other chemicals, or

  (ii) water, or

  (iii) the chemical itself (including polymerization).

  The remainder of Chapter I contains important administrative information on the effective date of the Code, certification, equivalence and how new products may be included. Definition of terms used within the context of the Code are also included in this chapter.

b. Chapter II - Cargo Containment

This chapter contains features of major significance to the design of ships; for the first time, measures to prevent the cargo from release appear as a ship design standard. Recognizing that the probability of damage resulting from collision or grounding may lead to uncontrolled release of the cargo, three degrees of physical protection for the cargoes were developed. The degrees of physical protection, or "ship types", define the location of the cargo with respect to the ship's side and bottom and the extent to which a ship should be capable of remaining afloat after damage. The assignment of ship types to the various cargoes takes into account the nature and severity of the product's hazard to the environment should it be released.

The highest standard of physical protection, Ship Type I, is required for those substances considered to have the greatest environmental hazard (i.e., which on release would have wide reaching effects beyond the immediate neighborhood of the vessel). Ship Type I requires the cargo to be located inboard from the side of the vessel a distance of 1/5 beam, and above the bottom a distance of 1/15 the beam. Further, Ship Type I requires the vessel to be able to withstand prescribed damages (two-compartment standard of subdivision and damage stability throughout its length).

Ship Type II is required for those cargoes with significant hazards but whose release does not have wide-reaching effects. Ship Type II requires the cargo to be located inboard from the side of the vessel a minimum distance of 760 mm (30") and above the bottom a distance of 1/15 the beam, thereby providing the cargo protection against low energy collisions and groundings which are often associated with vessels in port. Increased survivability of the vessel is also required. Ships of lengths in excess of 150 meters (492') must provide a two-compartment standard of subdivision and damage stability throughout ship length. Ships of less than 150 meters must meet a two-compartment standard of subdivision and damage stability in the cargo portion of the vessel, and a one-compartment standard of subdivision and damage stability for the engine room.

Ship Type III is prescribed for products having lesser hazards and more nearly described as being the normal tanker, although it is significant to note that increased survivability is also required.

Underlying all the ship types is the growing concern for the protection of the environment regardless of the product carried in the vessel. In determining the survival capabilities, the following damage conditions are assumed:

Collision:

Longitudinal Extent - 1/3 $L^{2/3}$ or 14.5 meters (47.6') whichever is less.

Transverse Extent - a distance of B/5 or 11.5 meters (37.7') whichever is less.

Vertical Extent - upward from the base line without limit.

Stranding:

Vertical Extent - a distance of B/15 or 6 meters (19.7") whichever is less.

Longitudinal Extent - for the forward .3L of the vessel a distance of L/10 or 5 meters whichever is less is assumed; for the remainder, a distance of 5 meters is assumed.

Transverse Extent - for the forward .3L of the vessel a distance of B/6 or 10 meters whichever is less is assumed; for the remainder, a distance of 5 meters is assumed.

These damage assumptions were based upon casualty information available to IMCO.

The cargo containment chapter also includes other major provisions which will affect design of ships.

- Cargo Segregation

Cargoes subject to this Code must be segregated from machinery and boiler spaces, accommodation spaces and other service areas. Cargoes which react in a hazardous manner with other cargoes must be segregated from those cargoes by cofferdams, void spaces or mutually compatible cargoes. Further, tanks containing cargoes which react in a hazardous manner with other cargoes must have separate piping and vent systems.

- Location and Arrangement of Accommodation Spaces

Accommodation spaces on vessels which carry cargoes subject to this Code must be located aft of cargo pumprooms and cargo tanks. The arrangements of the accommodation space must be such as to preclude cargo vapors from being drawn into it.

- Arrangement of Cargo Pump Rooms

This section requires the cargo pump room to be arranged in a manner to facilitate the removal of unconscious persons. Arrangements to deal with drainage and possible leakage from cargo pumps and valves must also be provided. The bilge system serving the pump room must be separate from the normal ship service bilge system and operable from outside the pump room. This section also requires that facilities be provided on board the vessels for storage of contaminated bilge water and tank washings.

- Cargo Piping

The sections dealing with cargo piping outline the design parameters for the piping systems and give considerations to the location of the cargo piping. For example, cargo piping may not be installed under the deck between the outboard side of the cargo containment spaces and the skin of the vessel unless the clearances required under the ship type section are maintained. These minimum distances may be reduced when it can be shown that damage to the piping would not cause release of the cargo. Cargo transfer control systems are also prescribed.

- Cargo Hose

This section requires that, if cargo hose is carried aboard the vessel, the hose must be designed for the service intended and to a burst pressure of five times the normal operating pressure of the hose.

- Tank Vent Systems

Vessels which carry cargoes subject to this Code must have vent systems designed to minimize the possibility of cargo vapor accumulating about the deck. Further, the vent systems are required to be arranged in such a manner so the vapor discharge is directed upward in the form of a jet.

Two types of tank vent systems are included in the Code. The first, open venting, is a system which offers no restriction except for friction losses to the free flow of cargo vapors from the tank is permitted for cargoes of lesser hazards. The second type, control venting, is a vent system using pressure vacuum relief valves fitted to each tank with vent exits extending to four meters above the deck. The vent exits from a controlled venting system must be located a distance of at least 10 meters (32.8 feet) from the nearest air intake or opening into accommodation or other service spaces. Control venting is required for tanks used to transport inflammable and/or toxic cargoes.

. Cargo Temperature Control

This section contains considerations for designing cargo temperature control systems. For example, the heating or cooling media must be compatible with the cargoes, i.e., water or steam may not be used with water-reactive cargoes. Provisions for excluding the co-mingling of contaminated heat transfer media are one of the other several considerations the designer must take into account.

. Materials of Construction

Vessels must be constructed of materials suitable for the cargoes to be carried. This section contains considerations to be taken into account in selecting the materials of construction for vessels which transport cargoes subject to this Code. These include the following:

(i) determining the corrosive effect of the cargo;
(ii) determining whether or not a hazardous reaction can take place between the cargo and the material of construction;
(iii) determining whether or not a planned lining or coating system is compatible with the intended cargoes; and
(iv) determining the ductility of the material at the operating temperature.

. Environmental Control of Vapor Spaces in Cargo Tanks

Recognizing that many cargoes included within the scope of this Code require measures to prevent self-reaction or to lessen the fire hazard, requirements are included for inerting, padding or ventilating the space above the cargoes. Attention is drawn to the need for having adequate supply of inert gas or padding on board, having means for determining or monitoring the spaces to insure the correct atmosphere is maintained, and to precautions that must be taken to prevent the generation of static electricity when admitting inert or pad gases into these spaces.

. Pump and Pipeline Identification

The deck of a modern chemical tanker is a labyrinth of piping and pumping systems. This section requires that pumps, valves and pipeline systems be distinctively marked to identify the tanks they serve. The purpose of this requirement is to provide a means of eliminating disastrous errors that can occur if a product is pumped into the wrong tank.

c. Chapter III - Safety Equipment and Related Considerations

This chapter prescribes requirements to make the vessel a safe working environment for the operating personnel.

The operation of chemical vessels requires a variety of cargo handling procedures, such as cargo transfer, maintaining cargo state, tank cleaning and other similar operations, each of which could present hazards to the vessel's personnel. Chapter III provides safeguards to reduce or eliminate these hazards.

. Ventilation in Cargo Handling Spaces

Pump rooms and other similar closed spaces which contain cargo handling equipment must be equipped with a mechanical ventilation system designed to insure sufficient air movement through the space to avoid the accumulation of toxic and/or flammable vapors and to insure sufficient oxygen to provide a safe working environment. The ventilation system must have a minimum capacity of thirty changes of air per hour based upon the total volume of the space. Further details on the ventilation system arrangement and layout are included.

Spaces which are not normally entered, such as cofferdams, duct keels, pipe tunnels and other spaces where cargo may accumulate must be capable of being ventilated. The ventilation system may either be permanent or of the portable type.

. Electrical Requirements

This section contains requirements for the type and location of electrical equipment that may be used aboard vessels that transport cargoes with flammable characteristics. Current practice for petroleum tankers was used as a basis for developing this section. It is intended the section will be updated when the International Electric Technical Commission's current work has been completed.

. Gauging

The Code provides for four different methods of gauging tanks as follows:

(i) Open: a device which makes use of an opening in the tank and will expose the gauge operator to the cargo;
(ii) Restricted: a device which penetrates the tank and, when in use, permits a small quantity of cargo to be released to the atmosphere;
(iii) Closed: a device which penetrates the tank but which, when in operation, keeps the tank's contents from being released; and
(iv) Indirect: a device which is independent of the tank.

The assignment of the type of gauging equipment to specific cargoes is based upon the toxicity of the product.

. Vapor Detection

Vessels which transport certain cargoes (i.e., those presenting toxic or flammable hazards) must be equipped with instrumentation capable of testing for concentrations of the cargo. The Summary of Minimum Requirements indicates what device must be carried for the individual cargoes.

- **Fire Protection**

This section requires that vessels which carry inflammable or combustible chemicals be fitted with a fixed fire protection system. Further, the vessels are required to have on board fire extinguishing media suitable for the cargo being carried. The section on fire protection is at present incomplete and will be revised and expanded when the current work of the IMCO Subcommittee on Fire Protection has been completed.

- **Personnel Protection**

This section contains the requirements for personnel protection equipment that must be provided aboard the vessels. Equipment, such as protective clothing, goggles, face shields and gloves, is required to be aboard for those persons who conduct cargo transfer. Other safety equipment, such as self-contained breathing apparatus, emergency respiration protection, explosion-proof lamps, emergency stretchers and decontamination showers, is also required.

d. Chapter V - Operational Requirements

Consideration was given to the Tanker Safety Guide (Chemicals) being prepared by the International Chamber of Shipping before developing a comprehensive chapter on vessel operation. Chapter V draws largely upon the operational recommendations contained in the "Interim Recommendations for Existing Ships" and enumerates the various requirements contained in the Code which have operational implications.

The operating requirement that establishes cargo size limits is one of major significance. At this time the Code includes "holding figures". In depth studies are to be conducted on this matter. The limits established are as follows:

- the quantity of a cargo required to be carried in a Type I ship should not exceed 1250 cubic meters (44,150 cubic feet) in any one tank; and

- the quantity of a cargo required to be carried in a Type II ship should not exceed 3000 cubic meters (105,960 cubic feet) in any one tank.

e. Chapter VI - Summary of Minimum Requirements

The Summary of Minimum Requirements is represented in the Code in the form of a Table and provides specific answers to the questions concerning the ship type, tank type, tank vents, etc., required to transport a given product. This Table represents a systematic approach to considering the hazard potential, the physical properties of the products in their transported state and the degree of containment provided elsewhere in the Code.

f. Chapter IV - Special Requirements

The special requirements included in the Code are grouped into three subject areas:

- Special Requirements for Certain Individual Cargoes;
- Special Requirements for Certain Groups of Products; and
- Special Requirements for Construction and Equipment.

g. Summary

The IMCO Chemical Code has been developed because of international concerns over personnel and port safety as a result of the risk created by vessels transporting dangerous chemicals. A philosophy of determining minimum containment standards based upon product hazards has been followed throughout. Underlying this philosophy has been the recognition that both personnel and port safety are also dependent upon the vessel being operated properly.

Even though the IMCO Code has been developed around ship's safety principles, it is equally applicable as an environmental protection standard, for measures to preserve and enhance the environment depend to a large extent on preventing the release of hazardous cargoes. The Code represents a major milestone in the attainment of goals to protect the marine environment.

REFERENCES TO SECTION IVC-1

1. Lakey, R.J., Recent Developments with Respect to Codes and Regulations Relating to the Bulk Carriage of Liquid Chemicals by Sea, Second International Symposium on the Transport of Hazardous Cargoes by Sea, May 11-14, 1971.

2. Intergovernmental Maritime Consultative Organization (IMCO), Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, Resolution A. 212 (VII), October 12, 1971.

2. 1973 IMCO CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS

The International Conference on Marine Pollution convened by IMCO in October 1973 achieved its main objective of concluding a new International Convention for the Prevention of Pollution from Ships, 1973. The new instrument contains provisions aimed at eliminating the intentional pollution of the marine environment by harmful substances and minimizing the accidental discharge of such substances. A harmful substance , as defined by the Convention, means any substance which, if introduced into the sea, is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea, and includes oil, noxious liquid substances other than oil, sewage and garbage.

The Convention applies to any ship of any type whatsoever including hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms operating in the marine environment. It covers all aspects of intentional and accidental pollution from ships by oil (Annex I), noxious substances carried in bulk (Annex II), noxious substances carried in packages (Annex III), sewage (Annex IV), and garbage (Annex V), but does not deal with dumping which is covered by the 1972 Dumping Convention nor the release of harmful substances directly arising from the exploration, exploitation and associated offshore processing of seabed mineral resources nor the release of harmful substances for purposes of legitimate scientific research into pollution abatement or control.

The text of the Convention is subdivided into seven major categories: (a) the Articles, (b) the five technical Annexes and (c) a series of Resolutions. A summarial description of some major points of the Convention follows.

a. Articles

The twenty articles basically define the general obligations to which the contracting states subject themselves upon accession to the Convention. They include, inter alia, the application of the Convention (Article 3), violations of the Convention (Article 4), detection of violations and enforcement of the Convention (Article 6), reports on incidents involving harmful substances (Article 8), methods of settling disputes (Article 10), entry into force of the Convention (Article 15), and amendment procedures (Article 18).

A particularly important feature of th[illegible]vention is that it incorporates provisions which will enable amendments to be made to the technical requirements contained in the Annexes and Appendices much more expeditiously than is the case in the existing 1954 Convention. For many such amendments, it will now be possible to employ what may be called a "tacit acceptance" procedure which will enable them to be brought into force after a predetermined period. This will considerably facilitate the task of keeping the Convention up-to-date and in line with modern technological progress. Proposed amendments to the Convention will be submitted to the Marine Environment Protection Committee for consideration and adoption.

The 1973 Convention will enter into force twelve months after it has been ratified by not less than 15 States, the combined merchant fleets of which constitute not less than fifty percent of the gross tonnage of the world's merchant shipping and will supersede the 1954 International Convention for the Prevention of Pollution of the Sea by Oil, as amended.

b. Annex I - Oil

This technical Annex includes the regulations for the prevention of oil pollution from ships. Oil is defined as petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products excluding those petrochemicals which are regulated by Annex II. An oil tanker means a ship constructed or adapted primarily to carry oil in bulk in its cargo spaces and includes combination carriers and any "chemical tanker" as defined in Annex II when it is carrying a cargo or part cargo of oil in bulk.

Chapter II contains the requirements for control of operational pollution, meant to include those discharges of oil from ships as a result of normal operations; i. e., tank washing, ballasting and bilge waste disposal. All tankers, for example, are restricted from discharging oil or oily wastes within 50 nautical miles from land.

Outside this area, the discharge cannot exceed an instantaneous rate of discharge of 60 liters per nautical mile; and in a single ballast voyage, the total quantity of oil discharged into the sea must not exceed 1/15,000 of total quantity of the particular cargo of which the residue formed a part for existing tankers and 1/30,000 for new tankers. Ships other than tankers are similarly restricted in their operations, i.e., the oil content of the effluent must be less than 100 parts per million for ship operation at more than 12 nautical miles from the nearest land. These criteria apply equally to both persistent (black) and nonpersistent (white) oils, but do not include clean or segregated ballast or the discharge from non-tankers of oily mixture which without dilution has an oil content not exceeding 15 parts per million. A significant feature embodied in the Convention in this connection is that the Mediterranean Sea, Black Sea, Baltic Sea, Red Sea and the Persian Gulf are designated as special areas in which oil discharge has been completely prohibited, with the exception of very small ships. In addition to the foregoing restrictions pertaining to discharge criteria, all oil tankers are required to be capable of operating in accordance with the following criteria:

- retention of oil on board with the load on top system,
- discharge of oily residues and mixtures to port reception facilities.

To meet the above requirements all new and existing oil tankers and other ships will, with certain exceptions, be required to be fitted with appropriate equipment, which includes oil discharge monitoring and control systems, oily water separating equipment or filtering systems, slop tanks, sludge tanks, piping and pumping arrangements, etc. Furthermore, new oil tankers will, if over 70,000 tons deadweight, be required to have segregated ballast tanks sufficient in capacity to provide adequate operating draft without need to carry ballast water in cargo oil tanks. However, this requirement does not call for the fitting of double bottom tanks.

Chapter III of Annex I contains the requirements for minimizing oil pollution from oil tankers due to side and bottom damage. It essentially incorporates the 1971 amendments to the 1954 Convention with respect to hypothetical oil outflow by setting an upper limit on individual tank sizes. Cargo tank sizes and arrangements are to be such that the hypothetical outflow anywhere in the length of the ship does not exceed 30,000 cubic meters or 400 $\sqrt[3]{DWT}$, whichever is greater, but subject to a maximum of 40,000 cubic meters. In addition, it places a level of survivability upon tankers involved in a casualty incident which damages their sides or bottoms.

c. Annex II - Noxious Substances

Annex II regulates the control of noxious (harmful) liquid substances transported in bulk other than oil. A chemical tanker is a ship constructed or adapted primarily to carry a cargo of noxious liquid substances in bulk and includes an oil tanker when carrying a cargo or part cargo of noxious liquid substances in bulk. The substances to which this Annex applies are subdivided into four categories depending upon their hazard to either marine resources, human health, amenities and other legitimate uses of the sea as follows:

. Category A - Noxious liquid substances which if discharged into the sea from tank cleaning or deballasting operations would present a major hazard to either marine resources or human health or cause serious harm to amenities or other legitimate uses of the sea and therefore justify the application of stringent anti-pollution measures.

. Category B - Noxious liquid substances which if discharged into the sea from tank cleaning or deballasting operations would present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify the application of special anti-pollution measures.

. Category C - Noxious liquid substances which if discharged into the sea from tank cleaning or deballasting operations would present a minor hazard to either marine resources or human health or cause minimal harm to amenities or other legitimate uses of the sea and therefore require some attention in operational conditions.

. Category D - Noxious liquid substances which if discharged into the sea from tank cleaning or deballasting operations would present a recognizable hazard to either marine resources or human health or cause minimal harm to amenities or other legitimate uses of the sea and therefore require some attention in operational conditions.

Several hundred such substances have been evaluated and included in the list appended to the Convention. It is envisaged that the list will be kept up-to-date, and new substances carried by sea will be gradually evaluated and included. See Appendix I.

It has been determined that the main problem with respect to marine pollution from these harmful substances is due to the discharge of wash water after tank cleaning. The varieties of chemical substances carried are many and, due to the problem of contamination from one cargo to the next, necessitate with some exceptions that each tank must be washed and completely cleaned prior to subsequent cargo loading.

The first portion of Annex II deals with the discharge of noxious liquid substances in terms of distance from nearest land, special areas (the Baltic and Black Seas), effluent concentrations and total permissible quantities. For outside special areas, mixtures and residues containing Category A substances are to be discharged to a shore facility to the maximum extent practicable until the effluent concentration falls to a predetermined level for the particular substance. The remaining tank residues which physically cannot be pumped ashore may be pumped at sea in accordance with certain provisions. Tank mixtures and residues with Category B and C substances may be discharged at sea when, in the ship's wake, concentrations less than 1 and 10 parts per million respectively will be obtained. Special discharge provisions for A, B and C substances include the following:

. the ship is proceeding in route at a speed of at least 7 knots;

. the discharge is made below the waterline, taking into account the location of seawater intakes;

. the discharge is made at a distance of not less than 12 nautical miles from the nearest land and in a depth of water of not less than 25 meters; and

. the maximum quantity of each substance discharged is strictly limited.

In addition, discharges of category A, B and C substances in special areas are even more stringently regulated.

The discharge of Category D mixtures and residues in all areas must satisfy the following conditions:

- The ship is proceeding in route at a speed of at least 7 knots;
- such mixtures are of a concentration not greater than one part of the substance in ten parts of water; and
- the discharge is made at a distance of not less than 12 nautical miles from the nearest land.

The Annex requires reception facilities at cargo loading and unloading ports and terminals for reception, without undue delay to ships, of such residues and mixtures containing noxious liquid substances as would remain for disposal from ships carrying them as a consequence of the application of the Convention. Also, ship repair ports undertaking repair to chemical carriers should have facilities adequate for the reception of residues and mixtures containing these substances.

The Annex incorporates by reference the IMCO Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk. This Code requires that ships carrying Category A or B substances be constructed with double hulls. This will enable these ships to drain and clean their cargo tanks more efficiently due to smooth tank surfaces and recessed suction wells. The polluting effect of using cargo tanks for ballast is mitigated to the extent that, as a rule, tanks are normally cleaned prior to taking ballast water aboard. In addition, tankers built with double hulls can use this space for segregated ballast purposes.

In all cases, chemical carriers are, so far as is reasonable and practicable, to remove the liquid cargo residues in the tanks, pumps and lines after discharge. This is especially critical in the case of pumps and pipelines which contain substantial amounts of residues even after blowing air or nitrogen through the lines after discharge.

d. Annex III - Packaged Harmful Substances

Annex III contains the regulations for the prevention of pollution by harmful substances carried by ships in packaged forms or in freight containers, portable tanks or rail and road tank wagons. Each contracting state is required to issue detailed requirements on packaging, marking and labelling, documentation, stowage, quantity limitations and other aspects aimed at preventing or minimizing pollution of the marine environment by harmful substances.

e. Annex IV - Sewage

Sewage is defined in this Annex as:

- drainage and other wastes from any form of toilets, urinals and water closet scuppers;

- drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises;

- drainage from spaces containing living animals; and

- other waste waters when mixed with the drainages defined above.

The discharge of sewage from ships into the sea is prohibited except when:

- The ship is discharging comminuted and disinfected sewage, using a system approved by the Flag State at a distance of more than four nautical miles from the nearest land, or sewage which is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land, provided that in any case, the sewage that has been stored in holding tanks shall not be discharged instantaneously but at a moderate rate when the ship is in route and proceeding at not less than 4 knots; the rate of discharge shall be approved by the State based upon standards developed by IMCO; or

. The ship has in operation an approved sewage treatment plant which has been certified by the State, under whose authority the ship is operating, to meet the operational requirements referred to in the Annex, and

(i) the test results of the plant are laid down in the ship's International Sewage Pollution Prevention Certificate (1973);

(ii) additionally, the effluent shall not produce visible floating solids in, or cause discoloration of, the surrounding water; or

. The ship is situated in the waters under the jurisdiction of a State and is discharging sewage in accordance with such less severe requirements as may be imposed by such State.

When sewage is mixed with wastes or waste water having different discharge requirements, the more severe requirements shall apply.

f. Annex V - Garbage

Garbage is defined in Annex V as all kinds of victual, domestic and operational waste, excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes to the present Convention. The disposal into the sea of all plastics is prohibited. For the other principal kinds of garbage, such as food wastes, wood dunnage and lining and packing materials which will float, paper, rags, glass, metal, bottles, crockery, etc., specific minimum distances from the nearest land have been set for disposal into the sea, e.g., 25 nautical miles for wood dunnage, lining and packing materials which will float. More stringent disposal regulations are provided for special areas, i.e., the Mediterranean Sea, Black Sea, Baltic Sea, Red Sea and Persian Gulf. Finally, when garbage is mixed with other discharges having different disposal or discharge requirements, the more severe requirements shall apply.

3. 1972 CONVENTION ON THE PREVENTION OF MARINE POLLUTION BY DUMPING WASTES AND OTHER MATTER

The Intergovernmental Conference on the Convention on the Dumping of Wastes at Sea adopted in November 1972 an Ocean Dumping Convention. The Convention, signed by the contracting governments on December 29, 1972, is similar to U.S. ocean dumping legislation contained in the Marine Protection, Research, and Sanctuaries Act of 1972 (P.L. 92-532) as amended in March 22, 1974 by P.L. 93-254. Under the Convention, nations agree to regulate all ocean dumping through national administrative authorities. No dumping is allowed without a permit. The disposal of wastes or other matter directly arising from, or related to the exploration, exploitation and associated off-shore processing of seabed mineral resources is not covered by the provision of this Convention.

Dumping, as defined by the Convention, means: (a) any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea; (b) any deliberate disposal at sea of vessels, aircraft, platforms or other man-made structures at sea. Dumping does not include: (a) the disposal at sea of wastes or other matter incidental to, or derived from the normal operations of aircraft, platforms or other man-made structures at sea and their equipment, other than wastes or other matter transported by or to vessels, aircraft, platforms or other man-made structures at sea, operating for the disposal of such matter or derived from the treatment of such wastes or other matter on such vessels, aircraft, platforms or structures; (b) placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention.

All dumping of extremely hazardous substances listed in Annex I of the Convention is prohibited except in an emergency. These prohibited substances include the following:

- Organohalogen compounds (i.e., chlorinated hydrocarbons).
- Mercury and mercury compounds.
- Cadmium and cadmium compounds.

- Persistent plastics and other persistent synthetic materials.

- Crude oil, fuel oil, heavy diesel fuel, lubricating oils, hydraulic fluids, etc.

- High level radioactive wastes and matter.

- Biological and chemical warfare agents.

The prohibitions of Annex I do not apply to substances which are rapidly rendered harmless by physical, chemical, or biological processes in the sea provided they do not:

- make edible marine organisms unpalatable, or

- endanger human health or that of domestic animals.

Dumping of other hazardous substances listed in Annex II is only allowed pursuant to a special permit issued by the national authority. Other materials may be dumped pursuant to a general permit granted after specified criteria have been met. Substances requiring special permits in each case of dumping include:

- Wastes containing significant amounts of materials such as arsenic, lead, copper, zinc, their compounds, organosilicon compounds, cyanides, fluorides, and pesticides (not covered by Annex I).

- For the dumping of large quantities of acids and alkalis, consideration is to be given to the possible presence of the above listed substances as well as berylluim, chromium, nickel, vanadium, and their compounds.

- Containers, scrap metal, and other bulky wastes liable to sink to the sea bottom which may present a serious obstacle to fishing or navigation.

- Low-level radioactive wastes.

The Convention requires each contracting nation to regulate the dumping of all material loaded in its ports for the purpose of being dumped at sea or loaded on a vessel or aircraft of its flag or registry in the territory of a nation not a part to the Convention. Participating nations are further required to maintain records concerning the nature and quantities of material which they permit to be dumped and the circumstances of such dumping. They must report this information periodically to an international organization established for administration of the Convention. Contracting parties are also to promote the disposal and treatment of waste and other measures to prevent or mitigate pollution caused by dumping.

D. NATIONAL STATUTES AND REGULATIONS

Various unilateral national actions, i.e., legislation, standards and regulations, have been initiated for the purpose of marine pollution abatement. Many of these actions impact upon the Maritime Administration Ship Construction Program in such a manner as to require the development of a modern, non-polluting U.S. flag commercial fleet. A discussion of these actions is included in order to provide a comprehensive review of national efforts being conducted in the abatement of marine pollution resulting from shipping.

1. NATIONAL ENVIRONMENTAL POLICY ACT OF 1969 (NEPA) (P. L. 91-190)

The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality (CEQ).

Section 102(2)(C) of NEPA and the amended CEQ Guidelines, as published in the Federal Register on August 1, 1973, require all Federal Agencies to include in every recommendation or report on proposals for legislation and other Federal actions significantly affecting the quality of the human environment, a detailed statement on the environmental impact of the proposed action. Underlying the preparation of such environmental impact statements is the mandate of both NEPA and Executive Order 11514 of March 5, 1970, that all Federal Agencies, to the fullest extent possible, direct their policies, plans and programs to protect and enhance environmental quality.

Section 102(2)(C) of NEPA further prescribes that prior to making any detailed statement, the responsible Federal official must consult with and obtain the comments of the Federal Agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate Federal, State and local agencies, which are authorized to develop and enforce environmental standards, will be made available to appropriate officials, as well as the public, and will accompany the proposal through the existing agency review processes.

The CEQ Guidelines specify that Federal actions include "projects and continuing activities supported in whole or in part through Federal contracts, grants, subsidies, loans or other form of funding assistance, or any projects involving a Federal lease, permit, license or certificate or other entitlement for use".

To supplement the CEQ Guidelines, two Administrative Orders have been issued within the Department of Commerce:

a. DOC Department Administrative Order 216-6, as amended, Statements on Proposed Federal Actions Affecting the Environment. This order prescribes the policies and procedures to be followed throughout the Department of Commerce in the preparation of environmental impact statements.

b. Maritime Administration (MarAd) Administrator's Order 600-1, Implementation of NEPA within the Maritime Administration, Procedures and Responsibilities. This order implements the provisions of NEPA and Department Administrative Order 216-6 and assigns responsibilities within MarAd for the assessment of programs originated from within and for the processing of requests for review and comment from other Federal agencies on the potential environmental impact of programs proposed by those agencies.

2. OIL POLLUTION ACT OF 1961 (P. L. 87-167)

This Act implements the provisions of the 1954 International Convention for the Prevention of Pollution of the Sea by Oil. The 1954 Convention prohibited the discharge of persistent oil or oily mixtures which foul the surface of the sea within certain prohibited zones. Oily mixtures capable of fouling the surface of the sea were defined as those containing 100 parts per million or more of oil in the mixture. In general, the prohibited zones in relation to tankers were all sea areas within 50 miles of land, with certain exceptions in the North Sea Zone and Atlantic Zone where the prohibited area extended 100 miles off the coasts of Europe and the United Kingdom. However, the 1954 Convention permitted the discharge of oily ballast and bilge waters from ships other than tankers when such ships are proceeding to a port not provided with reception facilities. Reservations in the 1954 Convention permitted U. S. statutes to apply to U. S. territorial waters.

3. OIL POLLUTION ACT AMENDMENTS OF 1973 (P. L. 93-119)

By these amendments, the United States will adopt the 1969 and 1971 Amendments to the 1954 International Convention for the Prevention of Pollution of the Sea by Oil.

a. The 1969 Amendments prohibit the discharge of oil subject only to certain specified exceptions for practical operating reasons. This change eliminates free zones in which the discharge of oil is not regulated.

b. The 1971 Amendments include three important international standards concerning marine pollution abatement as follows:

- A maximum oil outflow resulting from a single tanker casualty was approved.
- A standard shore connection was adopted to enable the ship's oily waste water discharge lines to be connected to shore reception facilities.

- Performance specifications for oily water separators and oil content meters were approved.

These Amendments are included in the 1973 International Convention for the Prevention of Pollution from Ships.

4. WATER QUALITY IMPROVEMENT ACT OF 1970 (Amendments to the Federal Water Pollution Control Act) (P. L. 91-224)

Congress declared in this Act that it is the policy of the United States that there should be no discharge of oil into or upon the navigable waters of the United States, adjoining shorelines or upon or into the waters of the contiguous zone.

Some essential features of the Act are:

a. A revolving fund to be appropriated to carry out the oil and hazardous substance spill cleanup operations.

b. The President to prepare and publish a National Contingency Plan for control of spills of oil and hazardous polluting substances.

c. The President to act to remove polluting spills of oil and hazardous substances.

d. The President to issue regulations consistent with maritime safety and with marine and navigation laws: (1) establishing methods and procedures for removal of discharged oil, (2) establishing criteria for the development and implementation of local and regional oil removal contingency plans, (3) establishing procedures, methods and requirements for equipment to prevent discharges of oil from vessels and from onshore facilities and offshore facilities.

e. The Environmental Protection Agency (EPA) to promulgate regulations: (1) designating hazardous substances and (2) establishing, if appropriate, recommended methods and means for the removal of such substances.

f. EPA to promulgate Federal standards of performance for marine sanitation devices designed to prevent the discharge of untreated sewage into the navigable waters of the U.S.

g. The U.S. Coast Guard to promulgate regulations governing the design, construction and installation of marine sanitation devices consistent with the EPA effluent standards.

h. The U.S. Coast Guard to certify marine sanitation devices before they are permitted to be installed on vessels.

i. All Federal Agencies operating shoreside facilities to insure compliance with the water quality standards of the Act.

5. FEDERAL WATER POLLUTION CONTROL ACT (FWPCA) AMENDMENTS OF 1972 (P.L. 92-500)

The most significant national goals of these Amendments which relate to the marine environment are:

a. The discharge of pollutants into the navigable waters be eliminated by 1985.

b. Wherever attainable, an interim goal of water quality which provides for protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983.

c. The discharge of toxic pollutants in toxic amounts be prohibited.

d. A major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone and the oceans.

The 1972 Amendments are directed primarily at water pollution from land-based municipal and industrial sources, but they do contain some provisions which relate to vessel pollution. Most of the vessel provisions are a reiteration of the 1970 Amendments; however, there are some major additions. In particular, the 1972 Amendments extend the present provisions concerning liability for cleanup costs which apply to oil under the Water Quality Improvement Act Amendments to hazardous substances and create a new penalty for the discharge of hazardous substances which cannot be cleaned up.

6. NATIONAL ACTIONS IMPLEMENTING THE FWPCA

a. Environmental Protection Agency Standard for the Discharge of Oil from Vessels (Federal Register, September 11, 1970). This standard implements Section 11 of the Water Quality Improvement Act of 1970 and Section 311 of the FWPCA Amendments of 1972. For the first time, quantities of discharged oil harmful to the public health or welfare were defined as those which:

- violate applicable water quality standards; or
- cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines; or
- cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

The Maritime Administration interprets a sheen as caused by an oily water discharge with an oil content of more than 15 ppm.

b. Environmental Protection Agency Standards for Marine Sanitation Devices (Federal Register, June 23, 1972). These standards respond to the mandate of Section 13 of the Water Quality Improvement Act of 1970 and Section 312 of the FWPCA Amendments of 1972 which require that EPA promulgate standards of performance for marine sanitation devices to prevent the discharge of untreated or inadequately treated sewage into or upon the navigable waters of the United States from vessels. The long range standard is for no discharge of sewage from vessels into U.S. waters.

c. U.S. Coast Guard Regulations for Pollution Prevention from Vessels and Oil Transfer Facilities (Federal Register, December 21, 1972). These regulations respond to the mandate of Section 11 of the Water Quality Improvement Act of 1970 and Section 311 of the FWPCA Amendments of 1972. These regulations are designed to reduce the probability of an accidental or intentional release of oil or oily wastes from normal vessel operations, from certain limited energy vessel accidents and during the bulk transfer of oil or oily wastes to or from vessels. They became effective on July 1, 1974.

d. National Oil and Hazardous Substances Contingency Plan (Federal Register,February 10, 1975). This Contingency Plan, originally published in June 1970 and August 1971 in compliance with the Water Quality Improvement Act and most recently in February 1975 in compliance with the 1972 FWPCA Amendments, provides a mechanism for coordinating the response to a spill of oil or hazardous polluting substances in U.S. national waters where there exists a threat to U.S. waters, shoreline or shelf-bottom.

This Plan, including the Annexes, provides for a pattern of coordinated and integrated response by Departments and Agencies of the Federal Government to protect the environment from the damaging effects of pollution discharges. It promotes the coordination and direction of Federal and State response systems and encourages the development of local government and private response capabilities.

The objectives of this Plan are to provide for efficient, coordinated, and effective action to minimize damage from oil and hazardous substance discharges, including containment, dispersal, and removal. The Plan, including the Annexes and regional plans, provides for: (1) assignment of duties and responsibility among Federal departments and agencies in coordination with State and local agencies; (2) identification, procurement, maintenance, and storage of equipment and supplies; (3) establishment or designation of a strike force to provide necessary services to carry out the Plan and establishment, at major ports, of trained and equipped emergency task forces; (4) a system of surveillance and reporting designed to insure the earliest possible notice of discharges of oil and hazardous substances to the appropriate Federal agency; (5) establishment of a national center to provide coordination and direction for operations in carrying out the Plan; (6) procedures and techniques to be employed in identifying, containing, dispersing, and removing oil and hazardous substances; (7) a schedule, prepared in cooperation with the States, identifying dispersants and other chemicals, if any, that may be used in carrying out the Plan; and (8) a system whereby the State or States effected by a discharge may be reimbursed for reasonable costs incurred in the removal of such discharge.

e. U.S. Coast Guard Certification Procedures and Design and Construction Requirements for Marine Sanitation Devices (Federal Register, January 30, 1975). These regulations are required by the FWPCA amendments of 1970 and 1972 and are consistent with the standards issued by the Environmental Protection Agency, with maritime safety, and with the marine and navigation laws. Areas covered are the design, construction, testing, certification, and manufacture of marine sanitation devices. Requirements apply to all new and existing vessels.

f. Environmental Protection Agency Proposed Pollution Abatement Regulations on Hazardous Substances (Federal Register, August 22, 1974). This Advance Notice of Proposed Rulemaking was issued with the intent to create a new Part 116 of Title 40 of the Code of Federal Regulations entitled "Designation of Hazardous Substances and Determination of Removability" pursuant to the authority of Section 311 of the 1972 FWPCA amendments. Section 311 (b)(2)(A) provides that the EPA Administrator shall develop and promulgate regulations designating as hazardous substances other than oil such elements and compounds which, when discharged in any quantity into or upon the navigable waters of the United States or adjoining shorelines or the waters of the contiguous zone, present an imminent and substantial danger to the public health or welfare, including but not limited to, fish, wildlife, shorelines, and beaches. Section

311 (b)(2)(B) requires that the designation of hazardous substances shall include a determination as to whether any such designated hazardous substance can actually be removed.

The Advance Notice suggests that substances which can reasonably be anticipated to present an imminent and substantial danger to public health and welfare would be selected using the following criteria:

- Any element or compound produced in excess of research quantities possesses sufficient danger potential to be considered as a candidate hazardous substance if it is lethal to: (a) one-half of a test population of aquatic animals in 96 hours or less at a concentration of 500 mg/l or less; or (b) one-half of a test population of animals in 14 days or less than administered as a single oral dose equal to or less than 50 mg/kg body weight for 24 hours; or (c) one-half of a test population of animals in 14 days or less when dermally exposed to an amount equal to or less than 200 mg/kg body weight for 24 hours; or (d) one-half of a test population of animals in 14 days or less when exposed to a vapor concentration equal to or less than 200 cm^3/m^3 (volume/volume) in air for one hour; or (e) aquatic flora as measured by a 50% decrease in cell count, biomass, or photosynthetic ability in 14 days or less at concentrations equal to or less than 100 mg/l.

- To be further considered for designation as a hazardous substance, any element or compound meeting the above criteria must have a reasonable potential for being discharged, i.e. spilled into a water body. Factors being considered in making this evaluation include the production quantities, modes of transportation, handling and storing practices, past spill experience, and physical-chemical properties of each substance.

Factors under study in making a determination as to a particular substance's actual removability from the water include the substance's solubility, density, physical phase, dispersion characteristics, aquatic stress potential such as acute lethality, residue which can remain, detectability of a substance in the water body, as well as, the current status of removal technology and availability of necessary equipment. Based upon these factors, EPA is considering making the determination that all of the approximately 400 substances listed in the Advance Notice of Proposed Rulemaking are not actually removeable.

Section 311 of the 1972 FWPCA Amendments also provides for the imposition of high penalties for the discharge, in harmful quantities of nonremovable hazardous substances into the navigable water of the United States.

7. PORTS AND WATERWAYS SAFETY ACT (PWSA) of 1972 (P.L. 92-340)

This Act is intended to promote the safety of ports, harbors, waterfront areas, and navigable waters of the United States. It consists of two sections as follows:

a. Title I, "Ports and Waterways Safety and Environmental Quality", gives the Secretary of the Department in which the Coast Guard operates the authority to take means to prevent damage to, or the destruction or loss of any vessel, bridge, or other structure on or in the navigable waters of the United States, or any land structure or shore area immediately adjacent to those waters; and to protect the navigable waters and the resources therein from environmental harm resulting from vessel or structural damage, destruction or loss.

b. Title II, "Vessels Carrying Certain Chemicals in Bulk", provides for the establishment of comprehensive minimum standards of design, construction, alteration, repair, maintenance and operation to prevent or mitigate the hazards to life, property and the marine environment. These standards will apply to all vessels documented under the Laws of the United States or entering the navigable waters of the United States.

8. NATIONAL ACTIONS IMPLEMENTING THE PWSA

a. Vessel Traffic Systems

The PWSA includes provisions for the safe navigation and operational control of vessels to prevent collisions and groundings in U.S. navigable waters. There is nothing new about the concept of controlling vessel movements since for many years the maritime industry has been accustomed to various forms of movement control. There have been sealanes, signals and even speed controls in some areas. The Coast Guard has the responsibility for the establishment, operation and maintenance of efficient and modern Vessel Traffic Systems (VTS) in congested ports and waterways of the United States. VTS are in operation in San Francisco Bay, California, and Puget Sound, Washington. VTS are also being planned for the Houston Ship Channel, New York Harbor and approaches including Long Island Sound, and New Orleans from the Gulf of Mexico to Baton Rouge.

In a related matter, regulations under the Bridge-to-Bridge Radiotelephone Act were promulgated in June 1972 and became effective on January 1, 1973. These regulations require the use of direct radio communications between vessels as they maneuver in close proximity to one another.

b. U.S. Coast Guard Proposed Regulations for Tank Vessel Design and Operation and for Vessel Traffic Management and Operation (Federal Register, June 28, 1974). These proposed regulations are intended to implement both Title I and Title II of the Ports and Waterways Safety Act of 1972 (P.L. 92-340) as amended. The proposed regulations consist of two parts: (1) amendments to 33 CFR Subchapter O - Pollution Abatement, proposed interim regulations that govern the design and operation of U.S. tank vessels certified to carry oil in the domestic trade, and (2) amendments to 33 CFR Subchapter P - Marine Traffic Requirements, advance notice of proposed rulemaking that covers general concepts for effective vessel traffic management and required navigational equipment and vessel operation in and out of U.S. ports.

A draft environmental impact statement was issued with the proposed changes to 33 CFR Subchapter O.

- Tank Vessel Design and Operation Requirements

The proposed interim regulations essentially adopt and implement the discharge and construction standards of Annex I (Oil) of the 1973 Marine Pollution Convention. These regulations apply only to U.S. flag oil carrying tankers operating in the domestic trade. They are applicable to chemical carriers when flammable cargoes are being transported.

- Vessel Traffic Management and Operating Procedures

The Coast Guard submitted, as an advance notice of proposed rulemaking, the concepts of vessel traffic management and operating procedures for all seagoing U.S. flag and foreign vessels operating in and out of U.S. ports, except for St. Lawrence Seaway, Great Lakes, and Lakes, Bays and Sounds vessels. However, for the latter class of vessels, all Captain of the Port (COTP) Orders and Vessel Traffic Systems will apply.

9. COASTAL ZONE MANAGEMENT ACT OF 1972 (P. L. 92-583)

This law is the result of the combined efforts of those pushing for a national oceans program and those concerned with the protection of the coastal environment. Under the Act, state governments are the focal point for coastal zone management. To assist the states in their work, a two-stage federal granting program is established. Grants to assist the state in developing a management program are followed by grants to assist the state in administering that program.

The coastal zone management program is administered by NOAA (National Oceanic and Atmospheric Administration) in the U.S. Department of Commerce, thus permitting full coordination with other ocean related programs such as the National Sea Grant Program. Only those coastal lands which have a direct and significant impact on coastal waters may be regulated under the Coastal Zone Management Act, thus insuring compatibility with future land use legislation.

The legislation does not require state participation. The incentive to participate is the desire for federal money. As an additional incentive, a participating state has an advantage in dealing with the Federal government if it has an approved coastal zone management program since all federal projects and permits must conform to the state's approved management program.

Under the federal program, states first receive planning grants to develop a management program. Once the management program is approved, states receive administrative grants. The Secretary of Commerce exercises continual approval authority over both the creation and administration of a state's coastal zone management program. If the Secretary believes the purposes of the Act are not being met, grants to that state may be discontinued.

10. CLEAN AIR ACT AMENDMENTS OF 1970 (P.L. 91-604)

The Clean Air Amendments of 1970 set in motion a nationwide, Federal and state program to achieve acceptable air quality. In essence, the Clean Air Act requires achievement of national standards of ambient air quality to protect public health by 1975. These standards are known as primary standards. Secondary standards will be designed to protect aesthetics, property and vegetation.

Section III of the Act requires that EPA implement regulations which will cover the emissions of shore facility stack gases for various industry plants including those relating to power generation. While these regulations would apply to shipyard facilities, they would not apply to ships because ships are not fixed installations. Nevertheless, MarAd subsidized ships must comply with state and local port emission standards. In addition subsidized ships must conform with the provisions of Section 70 of the Standard Specifications for Merchant Ship Construction which require the installation of smoke indicators.

E. MARITIME ADMINISTRATION STANDARD SPECIFICATIONS FOR MERCHANT SHIP CONSTRUCTION

MarAd has developed standard specifications to provide guidance for merchant ship designers preparing detailed ship specifications. Ship specifications are divided into sections, each dealing with a specific part, system or related series of systems. The MarAd Standard Specifications for Merchant Ship Construction have slightly over 100 such sections.

Significant improvements in ship construction and equipment for the purpose of pollution abatement are being integrated into new ship designs as well as for ships actually under construction. In this regard, MarAd's Standard Specifications for Merchant Ship Construction include sections for: (1) invoking compliance with regulatory body requirements; (2) contributing to the overall physical safety potential of the vessel; (3) enhancing the safe navigation and/or operation of the vessel; and (4) mitigating water and air pollution.

Section 70 of MarAd's Standard Specifications has periodically been updated to prescribe current standards and regulations of the Environmental Protection Agency, the Coast Guard and IMCO. It is the general intent of the MarAd Pollution Abatement Specifications to require that appropriate pollution control measures be taken in the design and operation of all merchant ships under the subsidy program in order to protect the quality of the marine environment from all ship-generated pollutants. These provisions include oil water separator, oily water slop tank, oil and sewage shoreside discharge, oil content meter, marine sanitation device, segregated ballast, pump emergency shutdown, overflow alarm, smoke indicator and many other features. The most recent revision of Section 70 was published in the Federal Register of February 10, 1975.

The MarAd specifications provide for collision avoidance radar which might also be considered a pollution abatement system. This system should be capable of tracking fixed and moving targets, providing information with respect to such objects, and sounding a warning signal if a collision is possible. Such a system provides for automatic radar watch together with course and speed information necessary to avoid collisions which could result in serious polluting incidents.

At the present time, there is no stipulation as to mandatory adherence to the Specifications' pollution control measures for ships other than oil tankers. It is general MarAd policy to specify the applicable portions of Section 70 for all ships before the design may be approved from a technical standpoint.

Section 70 does not now address itself to chemical-carrying ships, except in those areas that are applicable to all ships, such as bilge, and ballast wastes, fuel oil tank ballast wastes, fuel oil tank ballasting requirements, sewage treatment and stack emissions.

Comprehensive requirements exist in the U.S. Coast Guard regulations and in international regulations promulgated by IMCO. All Maritime Administration ships must comply with all applicable portions of U.S. Coast Guard regulations and those of other regulatory agencies named in each individual ship specification and in the Maritime Administration Standard Specifications.

F. TRAINING

An alternative approach to reducing marine pollution through the application of hardware is to improve the training of tanker crews and terminal personnel and to improve testing and certification procedures to insure that such personnel have the necessary skills. The importance of adequately trained personnel in marine transportation systems is graphically demonstrated in statistics on accidents in the Statistical Summary of Casualties to Commercial Vessels, 1 July 1971 to 30 June 1972, Proceedings of the Marine Safety Council, Department of Transportation, United States Coast Guard CG-129, January 1973. These statistics demonstrate the personnel error relationship to accidents and navigational casualties. Personnel faults were responsible for 31.8% of the casualties. In addition, a substantial number of other types of marine harmful substance spills have undoubtedly been caused by human failures of the type which proper training could correct. Appropriate training, testing, and certification of personnel in fields of pollution abatement and traditional maritime skills should be considered as a vital complement to advances in design and equipment.

The training, testing, and certification of marine personnel is a matter of law and regulations of the various maritime nations. In the U.S., the Coast Guard performs these functions. However, due to the international character of the maritime industry, it is necessary that international standards for personnel proficiency be developed.

1. IMCO STANDARDS

At the international level, the leading body responsible for development of international standards is the Intergovernmental Maritime Consultative Organization (IMCO), a functioning body of the United Nations. IMCO's Working Group on Technical Cooperation has concluded that: "There is a need for internationally accepted standards of training and certification in view of problems not only of maritime safety but also the prevention of pollution." The Working Group recommended that the matter be referred to IMCO's Maritime Safety Committee as a matter of urgency.

The Maritime Safety Committee in September 1971 established the Subcommittee on Standards of Training and Watchkeeping. Although it was clear that a major incentive for the establishment of the Subcommittee was the question of pollution prevention, it was also recognized that the scope of the Subcommittee's task started as the very basic framework of navigational safety. Therefore, primary attention has been directed toward standards for maintaining a safe navigational watch. Areas addressed by the Subcommittee include the following:

a. Basic principles to be observed in keeping a safe navigational watch.

b. Operational guidance for officers of the watch.

c. Mandatory minimum requirements for the certification of masters and officers in charge of a safe navigational watch.

d. Operational guidance for officers of the watch in port.

e. Training and qualifications of officers and crews of ships carrying hazardous chemicals in bulk.

Even after completion of IMCO development and consideration of documents of this nature, the task of securing formal adoption by maritime nations is long, laborious, and uncertain. The position of the U.S. delegation at the Subcommittee level has been to stress inclusion in the agenda on a priority basis those items aimed specifically at pollution abatement.

2. U.S. COAST GUARD REGULATIONS

In contrast to the lengthy and time-consuming IMCO procedures for reaching international agreement and the subsequent uncertainty in adequate policing of such agreements when finally adopted by the member nations, the U.S. Coast Guard has historically taken note of IMCO discussions when in the preliminary stage and has in many cases initiated regulatory requirements that meet or exceed the recommendations prior to their being made mandatory by IMCO.

For example, the Code of Federal Regulations, Title 46 - Shipping, Chapter I - Coast Guard, Department of Transportation, Parts 10, 12, 31, 71, 91, 105, 175, 176, 187, 188 and 189, dated October 1, 1973, promulgate new regulations that require all U.S. merchant marine officers and seamen on all documented ships to have additional knowledge of environmental pollution and of laws, regulations, and procedures to prevent environmental pollution. These regulations are in addition to requirements specified in Coast Guard regulations directly affecting "Tankermen" ratings on tankers.

These new U.S. Coast Guard regulations pertaining to merchant marine officers and seamen, specifically provide for the inclusion of questions in the area of pollution abatement in the various levels of examinations taken by merchant mariners for original issue or renewal of officers licenses or seamen's documents. By means of the examination questions, the U.S. Coast Guard achieves some measure of assurance that merchant mariners possess the basic knowledge necessary to minimize or avert environmental damage. Failure to satisfactorily answer these additional questions can lead to non-issue or non-renewal of the mariner's document. Further, subsequent pollution incidents found to be caused by personnel fault can lead to action by U.S. Coast Guard in suspension or revocation of documents. An immediate effect of the new regulations is an incentive on the part of seafaring personnel to acquire the necessary basic knowledge in pollution prevention and abatement. Full and effective indoctrination of seafarers, however, will depend on the availability of normal training or supervised on-the-job experience.

Both MarAd and the U.S. Coast Guard recognize the value of supervised on-the-job experience in the acquisition of necessary operating knowledge; however, the introduction of new technology, equipment, operational procedures and the desire for more effective protection of the environment lead to the conclusion that a combination of formal training with supervised on-the-job experience will yield a more comprehensive degree of knowledge and capabilities in the workforce.

3. TRAINING SUPPORT

Formal training programs for merchant marine personnel are offered in a variety of facilities both public and private. The major installations are the U.S. Merchant Marine Academy, the six State Maritime Academies and Colleges, the three Regional Training Centers operated by MarAd and several industry training centers operated under joint trusteeship of particular maritime unions and steamship company groups. All of these installations are in close contact with the U.S. Coast Guard and MarAd with particular concern for updating curriculum content in keeping with new skill and knowledge needs, whether enforced by regulation or not.

The U.S. Merchant Marine Academy, operated as a fully accredited college by MarAd for the education and training of new Engineering and Deck Officers, offers an environmental pollution control course consisting of two ten-week sessions.

MarAd's National Maritime Research Center at the U.S. Merchant Marine Academy is cooperating with the U.S. Coast Guard in a major revision of the Tankerman Manual, a U.S. Coast Guard publication specifically designed to cover the field of knowledge for the special skills required on board tank vessels. This revision of the Tankerman Manual covers new technologies, new operational procedures, and pollution control information in keeping with the intent of law and regulation. The Manual constitutes a basic reference work in the field, has direct use as a course text in formal training programs for seafarers endeavoring to acquire a "Tankerman" rating, and is the source for development of examination questions for issue of the rating document.

With specific reference to environmental protection courses designed for all seafarers and terminal personnel, regardless of ship type, MarAd is currently preparing a pollution abatement manual and course outline which will be made available to all existing training facilities for incorporation into their curricula. Development of this manual and course outline is in direct response to the "Final Opinion and Order of the Maritime Subsidy Board, Docket No. A-75, MarAd Tanker Construction Program, VI, Conclusion X", served August 30, 1973, as well as to the new pollution abatement regulations promulgated by the U.S. Coast Guard.

In MarAd's Regional Offices, ongoing short courses are offered to active merchant mariners in collision avoidance radar, Long Range Radio Navigation (LORAN), and fire-fighting and damage control. Since July 1, 1971, the U.S. Coast Guard has required that all licensed deck officers satisfactorily demonstrate their capabilities as qualified Radar

Observers every five years in order to continue sailing on their licenses. Successful completion of the radar courses at the Regional schools is accepted by the Coast Guard both for original issuance and for renewal of Radar Observer endorsements. The Regional schools are equipped with four modern computer-controlled radar simulators which present realistic navigational situations for direct training under life-like conditions. Only one other radar simulator available to active merchant mariners exists in the United States. This is located at the industry financed Maritime Institute of Technology and Graduate Studies, located in Linthicum, Maryland. The only facilities available to seafarers for fire-fighting and damage control training are the two schools sponsored by MarAd and operated by the Department of Navy in Bayonne, New Jersey, and San Francisco (Treasure Island), California.

Both the industry (unions and management) and the Government (U.S. Coast Guard and MarAd) are committed to the encouragement of professional training through the Federal, state and industrial facilities already mentioned. While the value of on-the-job experience under proper supervision is recognized and is relied upon by many maritime nations, the emphasis on combined formal training and practical experience in the U.S. has yielded a high level of proficiency. Continued progress is being made by government and industry in the area of formal training under the stimulus of applicable U.S. laws and regulations and industry's general self-interest in safety of navigation, including safety of personnel, property and the environment. As seaborne traffic increases, the need for this type of activity increases.

4. ENVIRONMENTAL EFFECTS

The environmental effects of improved proficiency of marine personnel are very difficult to quantify and qualify. However, statistics indicate that harmful substance spills of all types could be substantially reduced in this manner. Some generalizations can be made about the relative effectiveness of various approaches to personnel certification and proficiency.

Environmental effects vary according to alternatives in the personnel training and certification areas. The approach of developing IMCO standards for training and certification has the advantage of applying to a large percentage of the world's fleet and its seamen. However, the disadvantage in depending on IMCO is the long time required to reach agreement even on minimal levels of standards, the difficulty in enforcement, and the fact that not all maritime nations even to this point accept all IMCO standards.

U.S. Coast Guard regulations on the other hand provide for creation, implementation and effective enforcement of standards in a more significant, shorter time frame. A disadvantage in sole reliance on U.S. Coast Guard regulations is that these apply only to crews of U.S. flag ships. U.S. regulations may also in some instances be made applicable to foreign flag ships; however, the extent of this applicability is essentially limited to the immediate coastal zones of the U.S. and generally to the three-mile limit. It is an historically demonstrated fact that U.S. laws and regulations affecting U.S. flag ships are both more stringent and far more enforceable in matters of safety of personnel, property and environment than international conventions or treaties.

Personnel error has constantly been a major contributor to the level of pollution in the environment. Higher standards of personnel training and capability supplement the pollution abatement effect of improved hardware since higher levels of technology will require improvement in the knowledge and capabilities of operating personnel both aboard ship and at the terminal. More intensive and formalized training programs and more rigorous examination and certification procedures should result in significant reduction in marine pollution from shipping.

CHAPTER V

ALTERNATIVE ACTIONS FOR THE DISPOSAL OF HAZARDOUS WASTES

The term "hazardous waste" means any waste or combination of wastes which pose a substantial present or potential hazard to human health or living organisms because such wastes are lethal, nondegradable, or persistent in nature; may be biologically magnified; or may otherwise tend to cause detrimental cumulative effects. The objectives of hazardous waste treatment are the destruction or the recovery for reuse of hazardous substances to innocuous forms that are acceptable for uncontrolled disposal. Several unit processes are usually required for complete treatment of a given waste stream. (1)

One of the major categories of hazardous wastes is toxic chemical wastes. When properly conducted, incineration at sea is an effective and environmentally safe means for disposing of combustible toxic chemical wastes. To assure the safety of each burning action, an Environmental Protection Agency permit is required in accordance with the Marine Protection, Research and Sanctuaries Act of 1972. Incinerator ships offer flexibility, not only in the quantities and varieties of toxic chemical wastes effectively destroyed,but also with their mobility. Other means exist to dispose of chemical wastes. The chemical waste incinerator ship project is designed to supplement viable, environmentally safe, alternative methods.

A description of various treatment and disposal processes for toxic chemical wastes follows. Methods for disposing of hazardous wastes not suitable for incineration at sea are also described.

A. PHYSICAL TREATMENT (1)

The physical treatment processes are utilized to concentrate waste brines and to remove soluble organics and ammonia from aqueous wastes. Processes such as flocculation, sedimentation, and filtration are widely used; their primary function is the separation of precipitated solids from the liquid phase. Ammonia stripping is utilized for removing ammonia from certain hazardous waste streams. Carbon sorption removes many soluble organics from aqueous waste streams. Evaporation is utilized to concentrate brine wastes in order to minimize the cost of ultimate disposal.

1. REVERSE OSMOSIS

The physical transport of a solvent across a membrane boundary, where external pressure is applied to the side of less solvent concentration so that the solvent will flow in the opposite direction. This allows solvent to be extracted from a solution, so that the solution is concentrated and the extracted solvent is relatively pure. Almost any dissolved solid can be treated by reverse osmosis, provided the concentrations are not too high and it is practical to adjust the pH to range from 3 to 8.

2. DIALYSIS

A process by which various substances in solution having widely different molecular weights may be separated by solute diffusion through semipermeable membranes. The driving force is the difference in chemical activity of the transferred species on the two sides of the membrane. The oldest continuing commercial use of dialysis is in the textile industry. Dialysis is particularly applicable when concentrations are high and dialysis coefficients are disparate. It is a suitable means of separation for any hazardous wastes that form aqueous solutions.

3. ELECTRODIALYSIS

Similar to dialysis in that dissolved solids are separated from their solvent by passage through a semipermeable membrane. It differs from dialysis in its dependence on an electric field as the driving force for the separation. Electrodialysis is applicable when it is desired to separate out a variety of ionized species from an un-ionized solvent such as water.

Electrodialysis is applicable for the treatment of waste streams for which it is desirable to reduce the concentrations of ionizable species in the intermediate range (10,000 to 500 parts per million) over a broad range of pH (e.g., 1 to 14). If an effluent of concentration lower than 500 parts per million is desired, the electrodialysis effluent could be fed into another treatment process.

4. EVAPORATION

The removal of solvent as vapor from a solution or slurry. This is normally accomplished by bringing the solvent to its boiling point to effect rapid vaporization. Heat energy is supplied to the solvent, and the vapor evolved must be continuously removed from above the liquid phase to prevent its accumulation. The vapor may or may not be recovered, depending on its value. Thus, the principal function of evaporation is the transfer of heat to the liquid to be evaporated. Evaporation processes are widely used throughout industry for the concentration of solutions and for the production of pure solvents. Evaporation represents the most versatile wastewater processing method available that is capable of producing a high-quality effluent. It is, however, one of the most costly processes and is therefore generally limited to the treatment of wastewater with high solids concentrations or to wastewater where very high decontamination is required.

5. CARBON SORPTION

A process in which a substance is brought into contact with a solid and is held at the surface or internally by physical and/or chemical forces. The solid is called the sorbent and the sorbed substance is called the sorbate. The amount of sorbate held by a given quantity of sorbent depends upon several factors, including the surface area per unit volume (or weight) of the sorbent and the intensity of the attractive forces. Activated carbon has been historically used to remove organic and other contaminants from water. Activated carbon sorption has been used to remove dissolved refractory organics from municipal waste streams and to clean up industrial waste streams. It has been used to remove some heavy metals and other inorganics from water. Carbon sorption can remove most types of organic wastes from water. Those that have low removal by carbon include short carbon chain polar substances such as methanol, formic acid, and perhaps acetone. This process is being utilized to treat herbicide plant wastes. Also, full-scale carbon sorption units have been successfully used for petroleum and petrochemical wastes.

6. AMMONIA STRIPPING

The removal of ammonia from alkaline aqueous wastes by stripping with steam at atmospheric pressure. The waste stream, at or near its boiling point, is introduced at the top of a packed or bubble cap tray-type column and contacted concurrently with steam. Ammonia, because of its high partial pressure over alkaline solutions, is readily condensed and reclaimed for sale, and liquid effluents from a properly designed steam stripping column will be essentially ammonia free. This process is quite useful in the treatment of ammonia-bearing wastes. However, it can also be used to remove various volatile and organic contaminants from waste streams.

7. FILTRATION

The physical removal of the solid constituents from the aqueous waste stream by means of a filter medium. A slurry is forced against the filter medium. The pores of the medium are small enough to prevent the passage of some of the solid particles;others impinge on the fiber of the medium. Consequently, a cake builds up on the filter, and after the initial deposition, the cake itself serves as the barrier. The capacity of this process is governed by the flow rate of the fluid filtrate through the bed formed by the solid particles. Most of the aqueous hazardous waste streams which contain solid constituents can be treated by this process.

8. SEDIMENTATION

A process used to separate aqueous waste streams from the particles suspended in them. The suspension is placed in a tank, and the particles are allowed to settle out; the fluid can then be removed from above the solid bed. The final state is that of a packed bed resembling a filter cake if the process is allowed to continue long enough. Sedimentation is widely used throughout industry for treatment of waste streams for which there is a need for separation of suspended solids from the liquid phase.

9. FLOCCULATION

A process used when fine particles in a waste stream are difficult to separate from the medium in which they are suspended. These waste constituents are in the low and fractional micrometer range of sizes; they settle too slowly for economic sedimentation and are often difficult to filter. Thus, this process is applied to gather these particles together as flocculates, which allows them to settle much faster. The resulting sediment is less dense and is often mobile. The particles also filter more readily into a cake which is permeable and does not clog. Like sedimentation, flocculation is widely used throughout industry for treatment of waste streams for which there is a need for separation of suspended and precipitated solids from the liquid phase.

B. CHEMICAL TREATMENT (1)

The chemical treatment processes are a vital part of proper hazardous waste management. Neutralization is carried out in part by reacting acid wastes with basic wastes. Sulfide precipitation is required in order to remove toxic metals like arsenic, cadmium, mercury, and antimony. Oxidation-reduction processes are utilized in treating cyanide and chromium-6 bearing wastes.

1. ION EXCHANGE

The reversible interchange of ions between a solid and a liquid phase in which there is no permanent change in the structure of the solid. It is a method of collecting and concentrating undesirable materials from waste streams. The mechanism of ion exchange is chemical, utilizing resins that react with either cations or anions. Ion exchange technology has been available and has been employed for many years for removing objectionable traces of metals and even cyanides from the various waste streams of the metal process industries. Objectionable levels of fluorides, nitrates, and manganese have also been removed from drinking water sources by means of ion exchange. Technology has been developed to the extent that the contaminants that are removed can be recycled, readily transformed into a harmless state, or safely disposed of.

2. NEUTRALIZATION

A process utilized to prevent excessively acid or alkaline wastes from being discharged in plant effluents. Some of the methods used to neutralize such wastes are: (a) mixing wastes such that the net effect is a near-neutral pH, (b) passing acid wastes through beds of limestone, (c) mixing acid with lime slurries, (d) adding proper proportions of concentrated solutions of caustic soda (NaOH) or soda ash to acid wastewaters, (e) blowing waste boiler-flue gas through alkaline wastes, (f) adding compressed CO_2 to alkaline wastes, (g) adding sulfuric acid to alkaline wastes. Neutralization is utilized in the precipitation of heavy metal hydroxides or hydrous oxides and calcium sulfate.

3. OXIDATION

A process by which waste streams containing reductants are converted to a less hazardous state. Oxidation may be achieved with chlorine, hypochlorites, ozone, peroxide, and other common oxidizing agents. The method most commonly applied on a large scale is oxidation by chlorine. Oxidation is used in the treating of cyanides and other reductants.

4. REDUCTION

A process whereby streams containing oxidants are treated with sulfur dioxide to reduce the oxidants to less noxious materials. Other reductants that can be used are sulfite salts and ferrous sulfate, depending on the availability and cost of these materials. Reduction is used to treat chromium-6 and other oxidants.

5. PRECIPITATION

A process of separating solid constituents from an aqueous waste stream by chemical changes. In this process, the waste stream is converted from one with soluble constituents to one with insoluble constituents. This process is applicable to the treatment of waste streams containing heavy metals.

6. CHLORINOLYSIS (2)

A process that breaks down organic molecules and adds chlorine molecules to produce carbon tetrachloride, phosgene, and anhydrous hydrogen chloride, all of which have established commercial value. Uncertainties exist, however, with development of this technique to an operational plant capable of processing large quantities and varieties of toxic wastes in a timely and economic manner.

C. THERMAL TREATMENT (1)(3)

Thermal treatment methods are used for destroying or converting solid or liquid combustible hazardous wastes. Land-based incineration is the standard process used throughout industry for destroying liquid and solid wastes.

A vast number of different hazardous waste materials, representing a broad spectrum of physical and chemical characteristics, can be destroyed by incineration. However, temperature and residence time conditions necessary for complete destruction vary widely depending on the chemical structure and physical form of the waste. Also, the characteristics and capabilities of the major types of incinerators considered suitable for hazardous waste disposal differ widely. Thus, the ideal combination of incinerator type and model and temperature/dwell time conditions will vary widely for each waste.

1. ROTARY KILN INCINERATION

Process Principle: Slowly rotating cylinder mounted at slight incline to horizontal. Tumbling action improves efficiency of solid waste destruction. Technology adapted from lime processing.

Application: Most organic wastes; well suited for solids and sludges; liquids and gases fired through auxiliary nozzles.

Combustion Temperatures: 810° - 1650°C (1500° - 3000°F).

Residence Times: Several seconds to several hours (liquids and gases-short, solids much longer).

Economics: Installed capital - \$2800 - \$11,200/daily metric ton (\$2500 - \$10,000/daily ton). Kiln maintenance - 5-10% of installed cost/yr.

2. MULTIPLE HEARTH INCINERATION

Process Principle: Solid feed slowly moves through vertically stacked hearths; gases and liquids fed through side ports and nozzles. Current applications largely in sewage sludge incineration.

Application: Most organic wastes; well suited for solids and sludges, also handles liquids and gases.

Furnace Temperatures: (with sewage sludge) drying zone - 320-540°C (600-1000°F), incineration zone - 760-980°C (1400-1800°F)

Residence Times: Up to several hours for solids.

Economics: Basic dry solids (sludge 75% moisture), installed cost - \$55-\$495/Kg. /hr. (\$25-225/lb. /hr.) capacity, operating cost- \$3-\$24/metric ton (\$2-\$22/ton).

3. LIQUID INJECTION INCINERATION

Process Principle: Vertical or horizontal vessel; wastes atomized through nozzles to increase rate of vaporization.

Application: Limited to pumpable liquids and slurries (type of incinerators aboard the VULCANUS).

Combustion Temperatures: 650°-1650°C (1200°-3000°F).

Residence Times: .1-1 second.

Economics: Operating cost - \$.25 - \$65.00/1000 liters (\$1 - \$250.00/1000 gal.).

4. FLUIDIZED BED INCINERATION

Process Principle: Wastes are injected into a hot agitated bed of inert granular particles; heat is transferred between the bed material (often sand) and the waste during combustion.

Application: Most organic wastes; ideal for liquids, also handles solids and gases.

Combustion Temperatures: 750°-870°C (1400°-1600°F).

Residence Times: Seconds for gases, liquids; longer for solids.

Economics: Reported capital costs - For liquids \$265-\$635/liter/hr. (\$1000-\$2400/gal. /hr.), for solids - \$110-\$290/Kg. /hr. (\$50-\$130/lb. / hr.). Operating cost - approximately \$28/metric ton (\$25/ton) dry solids. Project operating costs - for liquids - \$.0025-\$.021/liter (\$.01-.08/gal.), for sludges - \$22-\$44/metric ton (\$20-\$40/ton) dry solids.

5. MOLTEN SALT PROCESS

Process Principle: Wastes are injected into a bed of molten salt (usually sodium carbonate) where combustion occurs; salts may react with and retain off gases.

Application: Most organic wastes.

Combustion Temperatures: 810-980°C (1500-1800°F)

Residence Times: 3/4 second average.

Economics: Proposed investment cost for complete portable 230Kg (500 lb)/hr, \$500,000; for a 90Kg (200 lb) hr. unit with salt regeneration, \$800,000.

6. WET OXIDATION - ZIMMERMAN PROCESS

Process Principle: Oxidation of organic materials in a liquid state under high pressure at moderate temperatures. Sulfur, nitrogen, and halogen breakdown products are retained in liquid effluent.

Application: Soluble and water miscible organic wastes.

Oxidation Pressure: 316,000 - 1,758,000 Kg/m^2 gauge (450-2500 psig).

Residence Time: 10-30 min.

Economics: Total treatment costs (capital and operating) - $.025 - .525/liter. Equipment costs - $200,000 - $600,000 (75 liters/min. (20 gpm) system).

7. PLASMA DESTRUCTION

Process Principle: Wastes are injected into high energy plasma; energy transfer degrades organic bonds.

Application: Work has been limited to gases, perhaps adaptable to liquid and solids.

Temperatures: 150°C (300°F).

Residence Times: 0.1 - 1.0 seconds

Economics: Installed cost (laboratory unit) - $10,000, cost of electricity - 22¢/Kg destroyed (10¢/lb.).

8. MULTIPLE CHAMBER INCINERATION

Process Principle: Wastes are combusted on a grate or hearth in an ignition chamber; gases travel through mixing and secondary combustion chambers; most common application is municipal refuse incineration.

Application: Limited to solid materials; sludges, powders, tars and other wastes not acceptable.

Combustion Temperatures: 540°C (1000°F) normal.

Residence Times: Solids-minutes, Gases-seconds.

Economics: Installed cost: $17.50-$37.50/hourly Kg capacity ($8.00-$17.00/hourly pound capacity). Operating costs: $16.00-$18.00/ metric ton ($15.00-$16.00/ton) (includes capital cost).

9. PYROLYSIS

Process Principle: Thermal decomposition in the absence of oxygen transforms organic materials into solids, liquids and gaseous organic materials of simpler structure.

Application: Primarily useful with solids and sludges; potential for resource recovery of breakdown products (primarily as fuel).

Retort Temperatures: 480-810°C (900-1500°F) normal.

Residence Times: 12-15 minutes normal.

Economics: (municipal refuse) Total investment cost $11,000-$15,000/daily metric ton capacity ($10,000-14,000/daily ton capacity). Project operating cost $4.50-$10/metric ton ($4-$9/ton).

At present all hazardous waste incinerators in the United States are land based. The following incineration criteria for such incineration activities are useful in precluding health hazards or environmental degradation. (3)

1. Generally speaking, only organic materials are candidates for incineration although some inorganics can be thermally degraded.

2. Chlorine-containing organics emit extremely corrosive hydrogen chloride gas upon incineration. Other halogens behave similarly. Materials of construction should be chosen accordingly, and suitable emission scrubbers provided (packed tower, venturi, or equivalent). Scrubbing solutions of caustic soda appear to be the most suitable. Combustion units have been developed which are capable of recovering useable hydrogen chloride.

3. Organic materials containing dangerous heavy metals (mercury, arsenic, selenium, lead, cadmium) should not be incinerated unless the fate of the metal components in the environment is known or can be satisfactorily controlled by air and water pollution control equipment. These heavy metals may be vaporized but more commonly will exist as an oxide in the ash or as a particulate. Resource recovery of metals from the ash or scrubber effluent should be considered. If the residuals are hazardous, landfilling of the ash or scrubber sludge should

be examined with care to ensure that health hazards or environmental degradation do not occur due to leaching of toxic metal ions to subsurface waters or wind dispersal of toxic ash. Encapsulation prior to burial or permanent storage may be necessary.

4. Sulfur-containing organic materials will normally emit sulfur oxide on incineration. Care should be taken to remove these materials from stack gases if present in appreciable concentration.

5. Formation of nitrogen oxides can be minimized by keeping incineration temperatures below 1100°C (2000°F).

6. The destruction ratio of a given material upon incineration is dependent to a large extent on the relationship of incineration temperature to dwell time at that temperature. The higher the temperature used, the shorter the permissible dwell time necessary to achieve a given destruction ratio. As a general rule most organic hazardous materials can be virtually completely destroyed at 1000°C (1830°F) at a dwell time of 2 seconds. Many are completely destroyed at lower temperature/dwell time conditions; a few require more rigorous conditions. Incineration of hazardous organics should not be carried out unless the necessary conditions are known or unless test burns are first conducted to determine off-gas characteristics.

7. The hazard posed by incineration of a hazardous material is largely a function of amounts, nature, and distribution of the combustion products entering the environment. These products may be undegraded hazardous material, partially degraded toxic breakdown products, or hazardous end-products such as sulfur oxides, hydrogen chloride, or heavy metals. They may exist as a gaseous or particulate emission to the atmosphere, or in the scrubber water, or as ash residue. Care must be taken that these materials are not dispersed or disposed of in concentrations capable of affecting health or damaging property or the environment. All applicable Federal, State, and local air emission and water effluent standards and regulations must be complied with.

8. Incinerators burning hazardous materials should be equipped with automatic feed cut-off provisions in the event of either a flame-out or a reduction in reactor temperature below the temperature known to give complete combustion. This will help to prevent emission of unburned or only partially degraded materials to the atmosphere in the case of equipment malfunction.

In conclusion, incineration ranks as an important and widely used device for converting wastes to less undesireable forms before dumping or dispersal. Combustion is applicable to gaseous, liquid, or solid wastes. It reduces residual bulk of many solid or liquid wastes, converts most organic materials into gases which are already part of the natural atmosphere and can be released directly into it, generates useful heat, uses readily available oxygen from air as its principal chemical agent, causes chemical processes that are comparatively well understood, and is readily carried out rapidly on large quantities of materials in apparatus of comparatively simple design. Disadvantages of combustion can be generation of noxious or toxic gases, smoke, and solid particulates. The generation of atmospheric pollutants can be largely controlled by proper design of the incinerator and by further processing of effluent gases before emitting them to the atmosphere. (4)

D. BIOLOGICAL TREATMENT (1)

Biological treatment processes can be used for biodegrading organic wastes; however, careful consideration needs to be given to the limitations of these processes. These systems can operate effectively only within narrow ranges of flow, composition, and concentration variations. Biological systems generally do not work on solutions containing more than 1 to 5 percent salts. Systems that provide the full range of biodegradation facilities usually require large land areas. Toxic substances present a constant threat to biological cultures. In summary, biological treatment processes should be used only when the organic waste stream is diluted and fairly constant in its composition.

1. ACTIVATED SLUDGE

A process in which biologically active growths are continuously circulated and contacted with organic waste in the presence of oxygen.

Normally, oxygen is supplied to the system in the form of fine air bubbles under turbulent conditions. The activated sludge is composed of the biologically active growth and contains micro-organisms that feed on the organic waste. Oxygen is required to sustain the growth of the micro-organisms. In the conventional activated sludge process, incoming wastewater is mixed with recycled activated sludge and the mixture is aerated for several hours in an aeration tank. During this period, adsorption, flocculation, and various oxidation reactions take place which are responsible for removing much of the organic matter from the wastewater. The effluent from the aeration tank is passed to a sedimentation tank where the flocculated micro-organisms or sludge settles out. A portion of this sludge is recycled as seed to the influent wastewater. The activated sludge process has been applied very extensively in the treatment of refinery, petrochemical, and biodegradable organic wastewaters.

2. AERATED LAGOON

The use of a basin of significant depth (usually 6 to 17 feet (1.83 to 5.19 meters)) in which organic waste stabilization is accomplished by a dispersed biological growth system and where oxygenation is provided by mechanical or diffused aeration equipment. Aerated lagoons have been used successfully as an economical means to treat industrial wastes where high-quality effluents are not required.

3. TRICKLING FILTER

The use of artificial beds of rocks or other porous media through which the liquid from settled organic waste is percolated. In the process, the waste is brought into contact with air and biological growths. Settled liquid is applied intermittently or continuously over the top surface of the filter by means of a distributor. The filtered liquid is collected and discharged at the bottom. The primary removal of organic material is not accomplished through filtering or straining action. Removal is the result of an adsorption process similar to activated sludge which occurs at the surfaces of the biological growths or slimes covering the filter media. Trickling filters have been used extensively in the treatment of such industrial wastes as acetaldehyde, acetic acid, acetone, acrolein, alcohols, benzene, butadiene, chlorinated hydrocarbons, cyanides, epichlorohydrin, formaldehyde, formic acid, ketones, monoethanolamines, phenolics, propylenedichloride, terpenes, ammonia, ammonium nitrate, nylon and nylon chemical intermediates, resins, and rocket fuels.

4. WASTE STABILIZATION PONDS

The use of large shallow basins (usually 2 to 4 feet (0.61 to 1.22 meters) deep) for the purpose of purifying wastewater by storage under climatic conditions that favor the growth of algae. The conversion of organics to inorganics, or stabilization, in such ponds results from the combined metabolic activity of bacteria, algae, and surface aeration. Waste stabilization ponds have been widely used where land is plentiful and climatic conditions are favorable. They have been used extensively in treating industrial wastewaters when a high degree of purification is not required. More recently, stabilization ponds have proven to be successful in treating steel mill wastes.

E. ULTIMATE DISPOSAL (1)

Disposal methods used vary depending upon the form of the waste stream (solid or liquid), transportation costs, local ordinances, etc. Dumps and landfills are utilized for all types of hazardous wastes; ocean disposal and deep-well injection are used primarily for liquid hazardous wastes. Engineered storage or a secure landfill is utilized for those hazardous wastes for which no adequate treatment processes exist.

1. LANDFILL DISPOSAL

A well-controlled and sanitary method of disposal of wastes upon land. Common landfill disposal methods are (a) mixing with soil, (b) shallow burial, (c) combinations of these. The utilization of a landfill procedures for the disposal of certain hazardous waste materials at a national disposal site in an industrial environment, or in municipal applications will undoubtedly be required in the future.

2. DEEP-WELL DISPOSAL

A system of disposing of raw or treated filtered hazardous waste by pumping it into deep wells where it is contained in the pores of permeable subsurface rock separated from other groundwater supplies by impermeable layers of rock or clay. Subsurface injection has been extensively used in the disposal of oil field brines (between 10,000 and 40,000 brine injection wells in the United States). The number of industrial waste injection wells in the United States has increased to more than 100. Injection wells can be used by virtually any type of industry that is located in a proper geologic environment and that has a waste product amenable to this method. Some industries presently using this method are chemical and pharmaceutical plants, refineries, steel and metal industries, paper mills, and coke plants.

3. LAND BURIAL DISPOSAL

A method adaptable to those hazardous materials that require permanent disposal. Disposal is accomplished by either near surface or deep burial. In near-surface burial, the material is deposited either directly into the ground or is deposited in stainless steel tanks or concrete lined pits beneath the ground. In land burial, the waste is transported to a selected site where it is prepared for final burial. Land burial is a possible choice for the hazardous materials that require complete containment and permanent disposal.

4. OCEAN DUMPING

The process of utilizing the ocean as the ultimate disposal sink for all types of waste materials (including hazardous wastes). There are three basic techniques for ocean disposal of hazardous wastes. One technique is bulk disposal for liquid or slurry-type wastes. Another technique is stripping obsolete or surplus World War II cargo ships, loading the ships with obsolete munitions, towing them out to sea, and scuttling them at some designated spot. The third technique is the sinking at sea of containerized hazardous toxic wastes. The broad classes of hazardous wastes dumped at sea have been categorized as follows: industrial wastes; obsolete, surplus, and nonserviceable conventional explosive ordinance; chemical warfare wastes; and miscellaneous hazardous wastes.

5. ENGINEERED STORAGE

A potential system to be utilized for those hazardous wastes (especially radioactive) for which no adequate disposal methods exist. An engineered storage facility would have applicability until such time as a method for permanent disposal of these wastes is developed. A near ground surface engineered storage facility must provide safe storage of the solidified hazardous wastes for long periods of time and retrievability of the wastes at any time during this storage. The ultimate goal is to transfer these wastes to a permanent disposal site when a suitable site is found.

F. PROVIDE NO ASSISTANCE UNDER THE CHEMICAL WASTE INCINERATOR SHIP PROJECT

An alternative available to the Secretary of Commerce is to provide no assistance under the Chemical Waste Incinerator Ship Project. Such action on the part of the Secretary would be counter to the spirit of the Marine Protection, Research, and Sanctuaries Act of 1972. In addition, the need to develop means for safe disposal of increasing quantities of hazardous chemical wastes would still exist. Two immediate effects of eliminating the Project would be: (1) the placing of an added burden on land-based chemical waste disposal facilities and (2) the use of foreign flag chemical waste incinerator ships.

As noted previously, incinerator ships offer flexibility, not only in the quantities and varieties of toxic chemical wastes effectively destroyed, but also with their mobility. The ships built under the Project are intended to supplement viable, environmentally safe, alternative methods of waste disposal. In many cases, incineration at sea will be environmentally safer than land-based disposal methods.

The use of U.S. owned, operated, and regulated incinerator ships instead of similar foreign flag vessels will not present substantial improvements in environmental safety due to ship generated pollution. Foreign flag incinerator ships must satisfy strict regulatory requirements of the Coast Guard and the Environmental Protection Agency in order to operate in U.S. territorial waters. The advantage in having U.S. flag incinerator ships lies in the element of control. In case of emergency, a U.S. flag incinerator ship can be made more readily available for service than a foreign flag ship.

REFERENCES TO CHAPTER V

1. Environmental Protection Agency, Report to Congress - Disposal of Hazardous Wastes, SW-115, 1974.

2. U.S. Air Force, Environmental Statement - Disposition of Orange Herbicide by Incineration, 411164, November 1974.

3. Environmental Protection Agency, Incineration in Hazardous Waste Management, SW-141, 1975.

4. American Society of Mechanical Engineers, Combustion Fundamentals for Waste Incineration, 74-19743, 1974.

CHAPTER VI

ADVERSE ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED UNDER THE PROJECT

A. USE OF MATERIALS

As indicated in Section IIID, the conversion of one or more small cargo vessels under the Project will require the use of quantities of steel and other mineral products. While a very large part of these minerals will eventually be recycled, the mining and processing of these materials do involve environmental harm in the form of land use change and air and water pollution. However, when the amounts of materials used are considered in terms of total production, the amounts are small if not negligible. In addition, it is questionable whether domestic production would be reduced, and hence the environmental effects reduced, if construction under the Project did not take place.

The operation of the Project vessels will also involve the consumption of bunker fuel and lube oil. The extraction and processing of these products involve impacts generally similar to those concerning materials used in construction. In a like manner, the amounts involved are very small, and it is reasonable to assume that the Project will have no effect upon total production.

B. POLLUTING SPILLS

Chapter III sets out the various types of pollution which Project vessels may possibly produce. Chapter IV describes measures which may be taken to lessen the amounts and effects of pollution from Project vessels. These include enforcement of national and international vessel design, construction and operational standards and regulations and other measures for controlling ship generated pollution. While reduction of pollution is possible and achieveable, some pollution is bound to occur. Operational discharges for the most part can be controlled within limits; however, accidental discharges, especially those from casualties, result from the fallibility of man and are more difficult to control. Various safety measures can reduce the chances of accidents and minimize the effects of them when they occur, but environmentally significant spills from accidents involving Project vessels could possibly happen.

When polluting discharges from Project vessels occur, they can have the following environmental effects. The marine environment is rich in both its variety and quantity of marine life. Pollution can effect, in varying degrees, all forms of marine plant and animal life from those that are the lowest in the food chain to those at the top. The degree of pollution, type of pollutant spilled, where the spill occurs, duration and the physical conditions under which it occurs determine the extent of the impact. After pollution has occurred, a normal balance may be regained in a short period of time or the impact may be more severe and recovery may require a span of many years. Little is known of what effect the chronic incremental discharge of ship generated pollutants may have on the marine food web. In addition to the effects upon plant and animal life, polluting discharges of the chronic type or major spills could affect beaches, water areas, and historic sites making them at least temporarily unusuable for recreational purposes. If such pollution incidents occurred during periods of normal heavy visitor use, loss of recreational enjoyment and economic benefit to the vicinity could be substantial. Fishing, water sports, boating and many other marine related activities could be made much less attractive for an indeterminate period, depending upon the promptness and efficiency of the cleanup operation.

C. INCINERATION EXHAUST

As noted in Section IIIC, the high temperature combustion at sea of chlorinated hydrocarbon wastes, under strictly observed safety regulations, has minimal damaging influence on the water of the ocean. With the incineration temperature normally at 1400°C or more and the residence time for the atomized waste in excess of 2 seconds, destruction of the organic chlorides is more than 99.9% complete. Conversion is principally to water vapor, carbon dioxide, and hydrogen chloride. Very small amounts of unburned hydrocarbons also exist as may chlorine vapor and trace compounds from the waste, e.g. metals. These hot gases are emitted from the incinerator stacks in a plume, which drifts downwind from the vessel, and generally fall into the ocean.

D. OTHER ADVERSE IMPACTS

The foregoing Sections detail the possible environmental impacts of Chemical Waste Incinerator Ship Project which cannot be avoided. The Project will also involve some other impacts which are of lesser significance or which can be attributed only in part to the Project. Small amounts of air, water, noise, and solid waste pollution will result from construction, operation, repair, and scrapping of Project vessels. As pointed out in the individual sections, these forms of pollution can be and are likely to be kept within the limits of local, state, and national standards for these forms of pollution. The Project is not expected to contribute to pressures for the development of new shipyards and port facilities.

CHAPTER VII

RELATIONSHIP BETWEEN LOCAL SHORT TERM USE OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG TERM PRODUCTIVITY

A. EFFECTS OF CHEMICALS SPILLS AND WASTE INCINERATION UPON LONG TERM PRODUCTIVITY OF THE OCEANS

The Chemical Waste Incinerator Ship Project will have a beneficial effect upon the long term productivity of the oceans. The project provides a vehicle whereby toxic chemical wastes can be disposed of in an environmentally compatible manner. A primary disposal method for these wastes in the past has been ocean dumping. Ocean dumping is gradually being phased-out as required by national regulations and international treaties.

To the extent that the Project calls for the transport by vessel of toxic chemicals in bulk with the attendant potential for spills, the Project could present a serious local threat to marine productivity. The potential hazards of chemical spills are described in Chapter III. Waste incineration, when carried-out in a safe and reliable manner, should have little adverse effect on the productivity of the oceans. A vessel with similar characteristics as those of the VULCANUS could be expected to burn as much as 100,000 metric tons of chemicals per year.

With increased regulation by international groups, such as IMCO, and by domestic agencies, such as EPA and the Coast Guard, the incidents of ship generated pollution should be reduced. Vessels built under the Project are to be designed, constructed, and operated according to the most stringent of these national and international standards. This fact, coupled with the useful function to be performed by the vessels, leads to the conclusion that the Project will have a beneficial effect upon the long term productivity of the oceans.

CHAPTER VIII

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

A. EFFECTS OF CHEMICAL SPILLS

The extent of potential chemical spillage from Project vessels has been detailed herein. Such spills may have locally irreversible and irretrievable effects, although there is a lack of data on this subject.

The major significance of such spillage in the marine environment is its potential effect on living things. "Marine life is interconnected in a web of interrelated food chains all of which depends in the end on the chemical situation in the marine environment. Diversity of species is an essential characteristic of these food webs, for diversity is associated with stability in ecological systems". (1)

At this time, there is no evidence that low level spillage has led to an irreversible commitment of resources, nor is there any conclusive evidence that it has not. More dramatic, though less probable, are the major spills that could occur through the loss of one of the Project's ships in the coastal zone. The extent and severity of such a spill's effects, including its irreversible and irretrievable injury to natural resources, would depend on the combination of location, amount and type of pollutant, time of year, weather and sea conditions. The chances of all these circumstances being exactly right for maximum damage and resulting irreversible consequences are in the staff's opinion, remote. It is not clear that spills of lesser impact would result in an irreversible commitment or damage to natural resources.

B. USE OF MINERALS IN VESSEL CONSTRUCTION AND OPERATION

The conversion and operation of Project vessels will involve the use of mineral resources, some of which cannot be recovered. In the construction of vessels, coal, limestone, and other materials are used to produce steel and other materials used in construction. In operation, the vessels will consume bunker fuel and lube oils. While many materials are recoverable, such as steel used in construction, other materials are not. The character of these materials is not unique, nor will the quantities used be such that their use is significant in terms of our national resources.

REFERENCES TO CHAPTER VIII

1. Schachyer and Serwer, "Marine Pollution Problems and Remedies", The American Journal of International Law, Vol. 65, 1971.

APPENDIX I

1973 IMCO MARINE POLLUTION CONVENTION - NOXIOUS AND OTHER LIQUID SUBSTANCES CARRIED IN BULK BY WATER

Reference: Intergovernmental Maritime Consultative Organization (IMCO), *1973 International Convention for the Prevention of Pollution from Ships, Annex II*.

APPENDIX I - NOXIOUS AND OTHER LIQUID SUBSTANCES CARRIED IN BULK BY WATER

LIST OF NOXIOUS LIQUID SUBSTANCES CARRIED IN BULK

Substance	UN Number	Pollution Category for operational discharge	Residual concentration (per cent by weight)	
		(Regulation 3 of Annex II)	(Regulation 5(1) of Annex II)	(Regulation 5(7) of Annex II)
	I	II	III *Outside special areas*	IV *Within special areas*
Acetaldehyde	1089	C		
Acetic acid	1842	C		
Acetic anhydride	1715	C		
Acetone	1090	D		
Acetone cyanohydrin	1541	A	0.1	0.05
Acetyl chloride	1717	C		
Acrolein	1092	A	0.1	0.05
Acrylic acid*	-	C		
Acrylonitrile	1093	B		
Adiponitrile	-	D		
Alkylbenzene sulfonate	-			
(straight chain)		C		
(branched chain)		B		
Allyl alcohol	1098	B		
Allyl chloride	1100	C		
Alum (15% solution)	-	D		
Aminoethylethanolamine (Hydroxyethyl-ethylene-diamine)*	-	D		
Ammonia (28% aqueous)	1005	B		
iso-Amyl acetate	1104	C		
n-Amyl acetate	1104	C		
n-Amyl alcohol	-	D		
Aniline	1547	C		

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* Asterisk indicates that the substance has been provisionally included in this list and that further data are necessary in order to complete the evaluation of its environmental hazards, particularly in relation to living resources.

Substance	I	II	III	IV
Benzene	1114	C		
Benzyl alcohol	-	D		
Benzyl chloride	1738	B		
n-Butyl acetate	1123	D		
sec-Butyl acetate	1124	D		
n-Butyl acrylate	-	D		
Butyl butyrate*	-	B		
Butylene glycol(s)	-	D		
Butyl methacrylate	-	D		
n-Butyraldehyde	1129	B		
Butyric acid	-	B		
Calcium hydroxide (solution)	-	D		
Camphor oil	1130	B		
Carbon disulphide	1131	A	0.01	0.005
Carbon tetrachloride	1846	B		
Caustic potash (Potassium hydroxide)	1814	C		
Chloroacetic acid	1750	C		
Chloroform	1888	B		
Chlorohydrins (crude)*	-	D		
Chloroprene*	1991	C		
Chlorosulphonic acid	1754	C		
para-Chlorotoluene	-	B		
Citric acid (10%-25%)	-	D		
Creosote	1334	A	0.1	0.05
Cresols	2076	A	0.1	0.05
Cresylic acid	2022	A	0.1	0.05
Crotonaldehyde	1143	B		
Cumene	1918	C		
Cyclohexane	1145	C		
Cyclohexanol	-	D		
Cyclohexanone	1915	D		
Cyclohexylamine*	-	D		
para-Cymene (Isopropyltoluene)*	2046	D		
Decahydronaphthalene	1147	D		
Decane*	-	D		

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* Asterisk indicates that the substance has been provisionally included in this list and that further data are necessary in order to complete the evaluation of its environmental hazards, particularly in relation to living resources.

Substance	I	II	III	IV
Diacetone alcohol*	1148	D		
Dibenzyl ether*	-	C		
Dichlorobenzenes	1591	A	0.1	0.05
Dichloroethyl ether	1916	B		
Dichloropropene - Dichloropropane mixture (D.D. Soil fumigant)	2047	B		
Diethylamine	1154	C		
Diethylbenzene (mixed isomers)	2049	C		
Diethyl ether	1155	D		
Diethylenetriamine*	2079	C		
Diethylene glycol monoethyl ether	-	C		
Diethylketone (3-Pentanone)	1156	D		
Diisobutylene*	2050	D		
Diisobutyl ketone	1157	D		
Diisopropanolamine	-	C		
Diisopropylamine	1158	C		
Diisopropyl ether*	1159	D		
Dimethylamine (40% aqueous)	1160	C		
Dimethylethanolamine (2-Dimethylamino-ethanol)*	2051	C		
Dimethylformamide	-	D		
1,4-Dioxane*	1165	C		
Diphenyl/Diphenyloxide, mixtures*	-	D		
Dodecylbenzene	-	C		
Epichlorohydrin	2023	B		
2-Ethoxyethyl acetate*	1172	D		
Ethyl acetate	1173	D		
Ethyl acrylate	1917	D		
Ethyl amyl ketone*	-	C		
Ethylbenzene	1175	C		
Ethyl cyclohexane	-	D		

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* Asterisk indicates that the substance has been provisionally included in this list and that further data are necessary in order to complete the evaluation of its environmental hazards, particularly in relation to living resources.

Substance	I	II	III	IV
Ethylene chlorohydrin (2-Chloro-ethanol)	1135	D		
Ethylene cyanohydrin*	-	D		
Ethylenediamine	1604	C		
Ethylene dibromide	1605	B		
Ethylene dichloride	1184	B		
Ethylene glycol monoethyl ether (Methyl cellosolve)	1171	D		
2-Ethylhexyl acrylate*	-	D		
2-Ethylhexyl alcohol	-	C		
Ethyl lactate*	1192	D		
2-Ethyl 3-propyl-acrolein*	-	B		
Formaldehyde (37–50% solution)	1198	C		
Formic acid	1779	D		
Furfuryl alcohol	-	C		
Heptanoic acid*	-	D		
Hexamethylenediamine*	1783	C		
Hydrochloric acid	1789	D		
Hydrofluoric acid (40% aqueous)	1790	B		
Hydrogen peroxide (greater than 60%)	2015	C		
Isobutyl acrylate	-	D		
Isobutyl alcohol	1212	D		
Isobutyl methacrylate	-	D		
Isobutyraldehyde	2045	C		
Isooctane*	-	D		
Isopentane	-	D		
Isophorone	-	D		
Isopropylamine	1221	C		
Isopropyl cyclohexane	-	D		
Isoprene	1218	D		
Lactic acid	-	D		
Mesityl oxide*	1229	C		
Methyl acetate	1231	D		
Methyl acrylate	1919	C		
Methylamyl alcohol	-	D		

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Substance	I	II	III	IV
Methylene chloride	1593	B		
2-Methyl-5-Ethyl-pyridine*	-	B		
Methyl methacrylate	1247	D		
2-Methylpentene*	-	D		
alpha-Methylstyrene*	-	D		
Monochlorobenzene	1134	B		
Monoethanolamine	-	D		
Monoisopropanolamine	-	C		
Monomethyl ethanolamine	-	C		
Mononitrobenzene	-	C		
Monoisopropylamine	-	C		
Morpholine*	2054	C		
Naphthalene (molten)	1334	A	0.1	0.05
Naphthenic acids*	-	A	0.1	0.05
Nitric acid (90%)	2031 2032	C		
2-Nitropropane	-	D		
ortho-Nitrotoluene	1664	C		
Nonyl alcohol*	-	C		
Nonylphenol	-	C		
n-Octanol	-	C		
Oleum	1831	C		
Oxalic acid (10–25%)	-	D		
Pentachloroethane	1669	B		
n-Pentane	1265	C		
Perchloroethylene (Tetrachloroethylene)	1897	B		
Phenol	1671	B		
Phosphoric acid	1805	D		
Phosphorus (elemental)	1338	A	0.01	0.005
Phthalic anhydride (molten)	-	C		
beta-Propiolactone*	-	B		
Propionaldehyde	1275	D		
Propionic acid	1848	D		
Propionic anhydride	-	D		
n-Propyl acetate*	1276	C		

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Substance	I	II	III	IV
n-Propyl alcohol	1274	D		
n-Propylamine	1277	C		
Pyridine	1282	B		
Silicon tetrachloride	1818	D		
Sodium bichromate (solution)	-	C		
Sodium hydroxide	1824	C		
Sodium pentachlorophenate (solution)	-	A	0.1	0.05
Styrene monomer	2055	C		
Sulphuric acid	1830/ 1831/ 1832	C		
Tallow	-	D		
Tetraethyl lead	1649	A	0.1	0.05
Tetrahydrofuran	2056	D		
Tetrahydronaphthalene	1540	C		
Tetramethylbenzene	-	D		
Tetramethyl lead	1649	A	0.1	0.05
Titanium tetrachloride	1838	D		
Toluene	1294	C		
Toluene diisocyanate*	2078	B		
Trichloroethane	-	C		
Trichloroethylene	1710	B		
Triethanolamine	-	D		
Triethylamine	1296	C		
Trimethylbenzene*	-	C		
Tritolyl phosphate (Tricresyl phosphate)*	-	B		
Turpentine (wood)	1299	B		
Vinyl acetate	1301	C		
Vinylidene chloride*	1303	B		
Xylenes (mixed isomers)	1307	C		

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LIST OF OTHER LIQUID SUBSTANCES CARRIED IN BULK

Acetonitrile (Methyl cyanide)
tert-Amyl alcohol
n-Butyl alcohol
Butyrolactone
Calcium chloride (solution)
Castor oil
Citric juices
Coconut oil
Cod liver oil
iso-Decyl alcohol
n-Decyl alcohol
Decyl octyl alcohol
Dibutyl ether
Diethanolamine
Diethylene glycol
Dipentene
Dipropylene glycol
Ethyl alcohol
Ethylene glycol
Fatty alcohols (C_{12}-C_{20})
Glycerine
n-Heptane
Heptene (mixed isomers)
n-Hexane
Ligroin
Methyl alcohol
Methylamyl acetate
Methyl ethyl ketone (2-butanone)
Milk
Molasses
Olive Oil
Polypropylene glycol
iso-Propyl acetate
iso-Propyl alcohol
Propylene glycol
Propylene oxide
Propylene tetramer
Propylene trimer
Sorbitol
Sulphur (liquid)
Tridecanol
Triethylene glycol
Triethylenetetramine
Tripropylene glycol
Water
Wine

APPENDIX II

U.S. COAST GUARD - HAZARD RATINGS OF CHEMICALS SHIPPED IN BULK BY WATER

Reference: U.S. Coast Guard, Evaluation of the Hazard of Bulk Water Transportation of Industrial Chemicals - a tentative guide, July 1973.

APPENDIX II - HAZARD RATINGS OF CHEMICALS SHIPPED IN BULK BY WATER

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Acetaldehyde CH_3CHO	4	3	1	2	2	3	2	2	0	1
Acetic Acid (Glacial) CH_3COOH	2	2	3	2	1	2	2	2	0	0
Acetic Anhydride $(CH_3CO)_2O$	2	3	3	3	1	2^a	2	3	2	0
Acetone CH_3COCH_3	3	1	0	0	1	1	1	2	0	1
Acetone Cyanohydrin $(CH_3)_2COHCN$	1*	1^b	2	4	4	3^a	3	2^b	3^b	0
Acetonitrile CH_3CN	3*	1	1	3	2	1	1	2	0	0
Acetyl Chloride CH_3COCl	3	4	4	3	2	3^a	2	3	4	0
Acrolein (Inhibited) CH_2CHCHO	3	4	3	4	4	3	3	3	0	3
Acrylic Acid (Inhibited) $H_2C:CHCOOH$	2	3	3	2	1	3^a	2	2	0	3
Acrylonitrile $H_2C:CHCN$	3*	3	1	3	4	3	2	3	0	3
Adiponitrile $NC(CH_2)_4CN$	1*	1	1	3	3	2	3	2	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Aldrin (powder) $C_{12}H_8Cl_6$	0	1	1	3	3	3	4	2	2	0
Allyl Alcohol CH_2CHCH_2OH	3	3	2	3	2	3	2	2	0	1
Allyl Bromide $CH_2:CHCH_2Br$	3	3	3	2		2^a	2	2	0	1
Allyl Chloride CH_2CHCH_2Cl	3*	3	2	3	2	1^a	2	2	0	1
Allyl Chlorocarbonate (Allyl Chloroformate) $CH=CHCH_2OC(:O)Cl$	3	3	3	3	3	3^{ND}	3	3	0	1
Allyl Trichlorosilane $CH_2:CHCH_2SiCl_3$	3	4	4	3	3	3	2	3	4	4
Aluminum Triethyl $Al(C_2H_5)_3$	4*	NA	4	3	0	2^a	3	4	4	0
N-Aminoethyl Ethanolamine $NH_2CH_2CH_2NHCH_2CH_2OH$	1*	1	3	1	1	1^a	3	3	0	0
Ammonia, Anhydrous NH_3	1*	4	2	2	2	2	2	3	2	0
Ammonia, Aqua (28%) NH_4OH	1*	2	2	2	2	3	2	3	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Amyl Acetate, iso $CH_3CO_2C_5C_{11}$	3	1	0	1	1	3	2	1	0	0
Amyl Acetate, primary $CH_3CO_2C_5H_{11}$	3	2	1	1	1	3	2	1	0	0
Amyl Alcohol,n $CH_3(CH_2)_4OH$	3	1	0	2	2	2	2	2	0	0
Amyl Chloride, n $C_5H_{11}Cl$	3	1	1	2	1	2^{ND}	2	1	0	0
Amyl Nitrite $C_5H_{11}NO_2$	3	0	4	1	1	1	2	3	0	4
Amyl Trichlorosilane $C_5H_{11}SiCl_3$	2	3	4	3	3	3^{ND}	2	3	4	1
Aniline $C_6H_5NH_2$	1*	1	1	3	3	2	4	3	0	0
Antimony Pentachloride $SbCl_5$	0	3	4	3		3	2	3	3	0
Aromatic Oil (Naphthalene, etc.)	1	1	1	1	1		4	2	0	0
Arsenic Acid, Liquid (75-80% solution) $H_3A_sO_4$	0	0	1	4	4	3	1	2	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Ashalt (Typical)	1	1	2^c	1	0	1	4	0	0	0
Benzene (Benzol) C_6H_6	3	1	1	3	1	3	2	1	0	0
Benzoyl Chloride C_6H_5COCl	1	4	4	2	2	2^a	2	3	4	0
Benzyl Chloride (Stabilized) (alpha-chlorotoluene) $C_6H_5CH_2Cl$	1	4	4	2	2	3	3	3	2	3
Benzyl Chlorocarbonate $C_6H_5CH_2CO_2Cl$	1	2	2	3	3	3	3	2	3	3
	Note	When heated to 155°C, decomposes to CO_2 & benzyl Cloride, Benzyl Chloride yields HCl and Phosgene								
Boron Trichloride (Liquid) BCl_3	0	4	4	3	2	1	2	4	4	0
Bromine (Liquid) Br_2	0	4	4	4	4	3	3	4	1	0
1,3 Butadiene (Inhibited) $CH_2:CHCH:CH_2$	4	1	1	1	0	1	1	2	0	3
Butane (Commercial) C_4H_{10}	4	0	0	0	0	0^2	0	0	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Butyl Acetate,n $CH_3COOCH_2CH_2CH_2CH_3$	3	1	1	2	0	2	2	1	0	0
Butyl Acetate, sec $CH_3COOCH(CH_3)(C_2H_5)$	3	1	1	2	1	2	2	1	0	0
Butyl Acrylate,n (Inhibited) $CH_2{:}CHCOOC_4H_9$	2	1	1	1	1	2^d	2	2	0	3
Butyl Alcohol,n $CH_3(CH_2)_2CH_2OH$	3	1	1	2	2	2	2	2	0	0
Butyl Alcohol, iso- $(CH_3)_2CHCH_2OH$	3	1	0	1	2	1	2	2	0	0
Butyl Alcohol,sec (SBA) $CH_3CH_2CHOHCH_3$	3	1	0	1	1	1	2	2	0	0
Butyl Alcohol, tert $(CH_3)_2COHCH_3$	3	1	0	1	2	1	2	2	0	0
Butylamine,tert $(CH_3)_3CNH_2$	3	2^c	2^c	3	3	3	2	3	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Butyl Benzyl Phthalate (BBP) $C_6H_4(COO)_2C_4H_9C_7H_7$	1	0	0	0	0	1[a]	3	1	0	0
t-Butyl Hydroperoxide $(CH_3)_3COOH$	2	1	1	2	3		1	4	0	4
1,3 Butylene Glycol $HOCH_2CH_2CH(OH)CH_3$	1	0	0	0	0	2[a]	1	2	0	0
n-Butyraldehyde $CH_3(CH_2)_2CHO$	3	2	1	2	1	3	3	2	0	1
n-Butyric Acid $CH_3(CH_2)_2CHO$	1	2	3	0	1	2	3	2	0	0
Camphor Oil (light)	2	0	1	1	3	1	2	2	0	0
Carbon Disulfide CS_2	4*	2	2	3	1	2	3	2	0	0
Carbon Tetrachloride CCl_4	0	2	1	4	2	2	2	1	0	0

Note: Self-accelerating decomposition, 190-200°F. Shock and heat sensitive; Spontaneous chemical reaction may occur if mixed with readily oxidizalbe, organic or flammable materials.

Revised 3/72

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Casinghead (Natural) Gasoline	4	1	0	1	1	2	1	0	0	0
Caustic Potash Solution KOH	0	0	4	1	2	3[a]	2	4	0	0
Caustic Soda Solution NaOH	0	0	4	1	2	3[a]	2	4	0	0
Chlorine Cl_2	0	4	2	4	2	3	2	4	1	0
Chlorine Trifluoride (liquid) ClF_3	0	4	4	4	4	2[a]	3	4	4	0
Chloroacetyl Chloride $ClCH_2C(:O)Cl$	0	3	4	3	2	2	2	2	3	0
Chlorobenzene C_6H_5Cl	3*	0	1	2	1	3	2	1	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Chloroform $CHCl_3$	1*	2	1	2	1	2	2	1	0	0
Chlorohydrins, Crude $CH_2OHCHOHCH_2Cl$	2*	2	1	3	3	2^a	2	2	0	0
Chloropicrin CCl_3NO_2	0	4	4	4	4	3	4	1	0	0
Chlorosulfonic Acid $ClSO_2OH$	0	4	4	4	2	3^a	2	4	4	0
Chromyl Chloride CrO_2Cl_2	0	4	4	4	4	4	2	4	4	0
Coal Tar Oil	3	1	1	2	2	2^a	4	2	0	0
Collodion (Nitrocellulose in Ether-Alcohol) (Solution, 40g pyroxylin, 750ml ether, 250 ml alcohol)	4^d	1	0	2	0	1	1	1	0	0
Note: Very hazardous; becomes explosive if solvent evaporates										
Creosote, Coal-Tar	1	2	3	2	2	3^a	4	1	0	0
Cresols (Mixed Isomers) $CH_3C_6H_4OH$	1	2	3	2	1	3	4	2	0	0
Cresylate Spent Caustic	0	1	4	2	3	3^a	4	3	0	0

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Crotonaldehyde $CH_3CH:CHCHO$	3	3	3	3	3	3[a]	3	2	0	1
Crude Oil (Petroleum)	1-3	0	1	1	1	2	4	0	0	0
Cumene $C_6H_5CH(CH_3)_2$	2	1	1	1	1	3	2	1	0	0
Cyanogen Bromide $CNBr$	0	4	4	4	4	3	3	3	1	1
Cyclohexane C_6H_{12}	3	1	1	2	1	2	2	0	0	0
Cyclohexanol $C_6H_{11}OH$	1	1	2	1	1	3	2	2	0	0
Cyclohexanone $C_6H_{10}O$	2	3	2	1	1	3	2	2	0	0
3-Cyclohexenyl Methyl 3-Cyclohexene 1-Carboxylate (DIENE 221) $C_{14}H_{20}O_2$	1	0	1	1	1	1	3	2	0	0
Cyclohexyl Trichlorosilane $C_6H_{11}SiCl_3$	1	2	4	3	3	3	2	3	4	2
Cyclopentane C_5H_{10}	3	1	1	1	2	1	0	2	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
p-Cymene $CH_3C_6H_4CH(CH_3)_2$	2	0	1	1	1	1	2	1	0	0
n-Decyl Alcohol $CH_3(CH_2)_8CH_2OH$	1	0	0	0	0	0[a]	2	2	0	0
Depentanized Aromatic Stream C_6-C_9 hydrocarbons	3	1	1	3	1		2	2	0	0
Diaminopropane (propylene diamine) $NH_2CH_2CHOHCH_2NH_2$	3	3	3	2	2		2	3	0	0
Dibutyl Phthalate (DBP) $C_6H_4(COOC_4H_9)_2$	1	0	0	0	0	1[a]	3	1	0	0
Dichlorethylene $CHCl:CHCl$	3	2	2	3	1	2	2	1	0	1
Dichlorobenzene, o $C_6H_4Cl_2$	1*	2	1	1	1	3	2	1	0	0
Dichlorodifluoromethane CCl_2F_2	0*	0	0	1	0	0[a]	0	1	0	0
Dichloro Dimethyl Silane $(CH_3)_2SiCl_2$ (Dimethyl Dichloro Silane)	3	4	4	3	3	3	2	3	4	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Dichloroethyl Ether, (β, β'), sym $ClCH_2CH_2OCH_2CH_2Cl$	2*	3	2	3	3	2[a]	2	1	0	0
1,2 Dichloropropane $CH_3CHClCH_2Cl$	3*	1	1	3	1	3[a]	2	1	0	0
1,3 Dichloropropene $CHCl:CHCH_2Cl$	3*	2	2	3	3	3	2	1	0	1
Dicyclopentadiene $C_{10}H_{12}$	3	1	1	2	1	1[a]	2	1	0	1
Diethanolamine (DEA) $(HOCH_2CH_2)_2NH$	1*	2	2[d]	2	1	1	2	3	0	0
Diethylamine $(C_2H_5)_2NH$ Revised 3/72	3*	3	2[d]	2	2	3	1	3	0	0
Diethylbenzene $C_6H_4(C_2H_5)_2$	2	1	1	1	1	3	2	1	0	0
Diethyl Dichlorosilane $(C_2H_5)_2SiCl_2$ (Dichloro Diethyl Silane)	3	4	4	3	3	3	2	3	4	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Diethylene Glycol $CH_2OHCH_2OCH_2CH_2OH$	1	0	0	1	1	1	0	2	0	0
Diethylene Glycol Monobutyl Ether $C_4H_9OCH_2CH_2OCH_2CH_2OH$	1	1	0	1	1	3	1	2	0	0
Diethylene Glycol Monoethyl Ether $CH_2OHCH_2OCH_2CH_2OC_2H_5$	1	0	0	0	1	3	1	2	0	0
Diethylene Glycol Monomethyl Ether $CH_3OCH_2CH_2OCH_2CH_2OH$	1	0	0	0	1	3	1	2	0	0
Diethylene Triamine $NH_2C_2H_4NHC_2H_4NH_2$	1*	2	2^d	2	2	2	3	3	0	0
Difluorophosphoric Acid, (anh) HPO_2F_2	0	2	4	2			2	3	1	0
Diisobutylene C_8H_{16}	3	0	1	0	1	1^a	2	1	0	1
Diisobutyl Ketone $(CH_3)_2CHCH_2COCH_2CH(CH_3)_2$	2	2	1	1	1	2	2	2	0	0
Diisooctyl Acid Phosphate $(C_8H_{17})_2HPO_4$	1	0	2	3			2	1	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Diisopropanolamine (DIPA) $(CH_3CHOHCH_2)_2NH$	1•	2	2[d]	2	2	2[a]	2	3	0	0
Diisopropyl Amine $[(CH_3)_2CH]_2NH$	3	3[c]	2[c]	4	2	3	2	3	0	0
Dimethylamine (DMA) Aqueous solutions containing between 40 and 60% amine by weight $(CH_3)_2NH$	4	3	2	3	2	3	2	3	0	0
Dimethyl Formamide (DMF) $(CH_3)_2NC(O)H$	2	2	2	3	2	2	0	1	0	0
Dimethyl Hydrazine, unsymmetrical (UDMH) (1,1 Dimethylhydrazine) $(CH_3)_2NNH_2$	4	3	4	4	4	2[a]	2	4	0	4
Dimethyl Sulfate $(CH_3)_2SO_4$	1	1	4	4	4	3[a]	2	3	1	0
Dimethyl Sulfide $(CH_3)_2S$	4	3	2	2		3[a]	4	1	0	0
Dioxane (1,4) $OCH_2CH_2OCH_2CH_2$	3	1	1	3	1	2[a]	2	1	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Dipentene $C_{10}H_{16}$	2	1	1	0	1	1	2	1	0	1
Diphenyl Dichlorosilane $(C_6H_5)_2SiCl_2$	1	2	4	3	3	3	3	3	4	1
Diphenyl-Diphenyl Oxide Mixtures (DOWTHERM A)	1	1	1	1	0	0^{ND}	3	0	0	0
Dipropylene Glycol $(CH_3CHOHCH_2)_2O$	1	0	0	1	0	1	0	2	0	0
Dodecyl Benzene (Commercial) $C_6H_5C_{12}H_{25}$	1	0	0	0	1	3	3	1	0	0
Dodecyl Trichlorosilane $C_{12}H_{25}SiCl_3$	1	2	4	3	3	3	3	3	4	1
Epichlorohydrin $ClCH_2\underbrace{CHCH_2O}$	3*	3	3	4	3	3	2	3	1	2
Ethoxytriglycol $C_2H_5O(C_2H_4O)_3H$	1	0	0	0	0	1^a	1	2	0	0
Ethyl Acetate $CH_3COOC_2H_5$	3	1	1	2	1	2	2	1	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Ethyl Acrylate (Inhibited) $CH_2:CHCOOC_2H_5$	3	3	2	3	2	2	2	2	0	3
Ethyl Alcohol (Ethanol) C_2H_5OH	3	1	0	1	1	1	1	2	0	0
Ethyl Benzene $C_6H_5C_2H_5$	3	2	2	2	1	3	2	1	0	0
2-Ethylbutyraldehyde $(C_2H_5)_2CHCHO$	3	1	1	2	2	3	2	2	0	1
Ethyl Chloride C_2H_5Cl	4*	1	1	1	0	1^a	1	1	0	0
Ethyl Chlorocarbonate (Ethyl Chloroformate) C_2H_5OOCl	3	3	3	3	3	3^{ND}	3	2	2	0
Ethyl Dichlorosilane $C_2H_5SiCl_2$	3	4	4	3	3	3	2	3	4	1
Ethyl Ether (Diethyl Ether) $(C_2H_5)_2O$	4*	1	0	2	0	1^a	1	1	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Ethyl Formate $HCOOC_2H_5$	3	2	3	3	2	2^{ND}	2	1	1	0
2-Ethyl Hexanol-1 $CH_3(CH_2)_3CHC_2H_5CH_2OH$	1	1	1	1	1	1^{a}	2	2	0	0
Ethyl Nitrate $C_2H_5ONO_2$	3					1^{ND}			0	4
Ethyl Nitrite C_2H_5ONO	4			3		1^{ND}			0	4
Ethvl Phenyl Dichlorosilane $C_2H_5(C_6H_5)SiCl_2$	2	2	4	3	3	3	3	3	4	1
2-Ethyl, 3-Propyl Acrolein $C_3H_7CH:C(C_2H_5)CHO$	2	3	2	2	1	2^{a}	2	2	1	2
Ethyl Trichlorosilane $C_2H_5SiCl_3$	3	4	4	3	3	3	2	3	4	1
Ethylene $H_2C:CH_2$	4	0	0	1	0	1	0	1	0	2

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Ethylene Cyanohydrin $CH_2(OH)CH_2CN$	1^{e}	0	0	2	1	2^{a}	2	2	0	0
Ethylene Diamine $NH_2CH_2CH_2NH_2$	3^{e}	3	3^{d}	3	2	3	2	3	0	0
Ethylene Dibromide CH_2BrCH_2Br	0^{e}	1	1	3	3	3^{a}	2	1	0	0
Ethylene Dichloride CH_2ClCH_2Cl (Known as Dutch Oil)	3^{e}	2	2	3	3	2	2	1	0	0
Ethylene Glycol CH_2OHCH_2OH	1	0	0	1	2	1	1	2	0	0
Ethylene Glycol Monobutyl Ether (Butyl Cellusolve) $HOCH_2CH_2OC_4H_9$	1	1	1	2	2	2	1	2	0	0
Ethylene Glycol Monoethyl Ether Cellosolve Solvent $HOCH_2CH_2OC_2H_5$	2	1	1	2	1	2	1	2	0	0
Ethylene Glycol Monoethyl Ether Acetate (Cellosolve Acetate) $CH_3COOCH_2CH_2OC_2H_5$	2	1	1	1	1	2^{a}	2	1	0	0
Ethylene Glycol Monomethyl Ether (Methyl Cellosolve) $CH_3OCH_2CH_2OH$	2	1	1	2	2	2	1	2	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Ethylene Oxide $\overline{CH_2CH_2O}$	4	3	3	2	3	2^a	1	3	1	4^e
Ethylenimine $\overline{CH_2CH_2NH}$	3*	3	2	4	4	3^a	3	3	1	3
Ethylhexaldhyde $C_4H_9CH(C_2H_5)CHO$	2	1	2	1	2	2^a	2	2	0	1
2-Ethylhexyl Acrylate (Inhibited) CH_2:$CHCOOCH_2(C_2H_5)C_4H_9$	1	0	1	1	1	2^a	2	2	0	3
Ethyl Trichlorosilane $C_2H_5SiCl_3$	3	4	4	4			2	2	3	1
Fluosilicic Acid (22-25%) H_2SiF_6	0	0	3	3		3^a	0	1	0	0
Flusosulfonic Acid HSO_3F	0	4	4	3		2^a	2	4	4	0
Formaldehyde Solution (37-50%) HCHO	2*	3	2	3	3	3	2	2	0	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Formic Acid, Aqueous Solutions containing 95% acid by weight) HCOOH Revised 3/72	2	3	3	3	3	2	2	2	0	0
Furfural (furfurol) C_4H_3OCHO	2	2	2	3	3	3	2	2	0	1
Furfuryl Alcohol $C_4H_3OCH_2OH$	1	2	1	2	2	3	1	2	0	0
Gasoline, Commercial	3	1	1	2	1	2	2	0	0	0
Glycerine (glycerol) $CHOH(CH_2OH)_2$	1	0	0	0	0	0	0	2	0	0
Glycol Diacetate $CH_3COOCH_2CH_2COOCH_3$	1	0	0	0	1	2[a]	2	1	0	0
Glyoxal, 50% Aqueous Solution CHOCHO	1*	1	1	1	1	1[a]	1	2	0	1
Heptane, n $CH_3(CH_2)_5CH_3$	3	0	1	1	1	1	2	0	0	0
Heptene, α-isomers (Heptylene) C_7H_{14}	3	1	1	0	0	1	2	1	0	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Hexadecyl Trichlorosilane $C_{16}H_{33}SiCl_3$	1	2	4	3	3	3	3	3	4	1
Hexafluorophosphoric Acid HPF_6	0	2	4	2			2	3	0	0
Hexamethylene Diamine $H_2N(CH_2)_6NH_2$	1	1^c	2^c	3	2	3	1	3	0	0
Hexane, n- $CH_3(CH_2)_4CH_3$	3	0	0	1	1	1	1	0	0	0
Hexylene Glycol $CH_3CH(OH)CH_2C(OH)(CH_3)_2$	1	1	0	0	1	2^a	1	2	0	0
Hexyl Trichlorosilane $C_6H_{13}SiCl_3$	1	2	4	3	3	3	3	3	4	1
Hydrazine, anhydrous H_2NNH_2	4	3	4	4	4	3	2	4	0	4
Hydrobromic Acid 40% HBr	0	3	3	3	2	2^a	2	3	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Hydrochloric Acid Aqueous (28-35%) HCl	0	3	3	2	2	2	2	3	0	0
Hydrocyanic Acid (Prussic Acid) HCN	4	2	1	4	4	4	1	3	0	3
Hydrofluoric Acid Aqueous (70%) HF	0	4	4	4	4	3	2	3	0	0
Hydrogen Chloride (Anhydrous) HCl	0	4	3	3	2	2	2	4	2	0
Hydrogen Fluoride (Anhydrous) HF	0	4	4	4	4	3	2	4	2	0
Hydrogen Peroxide (50% stabilized) H_2O_2	0^d	2	3	1	1	3^e	1	4^d	0	3
2-Hydroxyethyl Acrylate (Inhibited) HEA $CH_2=CHC(O)CH_2CH_2OH$	1	4	4	4	3	3^a	1	1	0	3
Isobutyl Acetate $CH_3COOCH_2CH(CH_3)_2$	3	1	1	2	1	1^a	2	1	0	0
Isodecyl Acrylate $CH_3COOC_{10}H_{21}$	1	1	1	1	1	2^a	2	2	0	3

Ratings of Chemicals

CHEMICALS	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Isobutyl Alcohol $(CH_3)_2CHCH_2OH$	3	1	0	1	2	1	2	2	0	0
Isobutyraldehyde $(CH_3)_2CHCHO$	3	2	1	2	2	2[a]	3	2	0	1
Isodecaldehyde $C_9H_{19}CHO$	1	1	1	1	1	1[a]	2	2	0	1
Isodecanol (Mixed) $C_{10}H_{21}OH$ and isomers	1	0	2	0	0	1[a]	2	2	0	0
Isooctane $(CH_3)_2CHCH_2C(CH_3)_3$	3	1	1	2	1	2	2	0	0	0
Isooctanol $C_7H_{15}CH_2OH$	1	0	0	1	1	3	2	2	0	0
Isooctene $(CH_3)_3C\text{-}CH{=}(CH_3)_2$	3	1	1	2	1	2	2	1	0	1
Isooctyl Aldehyde $C_7H_{14}CHO$	2	1	0	1	1	1[a]	2	2	0	1
Isopentaldehyde C_4H_9CHO	3	1	1	1	2	3[a]	2	2	0	1

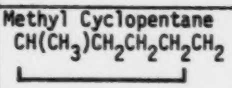
Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Isopentene $(CH_3)_2CHCHCH_2$	4	1	1	2	1	2	2	1	0	1
Isophorone $\underline{COCHC(CH_3)CH_2C(CH_3)_2}CH_2$	1	2	2	2	1	3^a	2	2	0	0
Isoprene $CH_2:C(CH_3)CH:CH_2$	4	1	1	1	0	1^a	1	2	0	3
Isopropyl Alcohol (IPA) $(CH_3)_2CHOH$	3	1	0	2	2	2	1	2	0	0
Isopropyl Amine (MIPA) $(CH_3)_2CHNH_2$	4	3^c	2^c	4	2	3	2	3	0	0
Isopropyl Acetate $(CH_3)_2CHOOCCH_3$	3	1	1	2	1	1	2	1	0	0
Isopropyl Ether $(CH_3)_2CHOCH(CH_3)_2$	3	1	1	1	1	2^a	2	1	0	0
Jet Fuel, JP-3	3	1	1	1	1	1	2	0	0	0
Jet Fuel, JP-4	3	1	1	1	1	1	3	0	0	0
Jet Fuel, JP-5	1-2	1	1	1	1	1	3	0	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Kerosene	2	1	1	1	1	1	3	0	0	0
Maleic Anhydride $HCC(O)OC(O)CH$	1	2	2	1	2	2^f	1	3	2	0
Mesityl Oxide $(CH_3)_2CCHCOCH_3$	3	2	2	2	2	3^a	2	2	0	1
Methane (Marsh Gas) CH_4 (Natural Gas)	4	0	0	0	0	0	0	0	0	0
Methoxy Triglycol $CH_3O[C_2H_4O]_3H$	1	0	0	0	0	1^a	1	2	0	0
Methyl Acetate CH_3COOCH_3	3	2	0	1	1	2^a	1	1	0	0
Methyl Acetone (Mixture of 70-80% acetone in methyl acetate) $CH_3COOC_2H_5.(CH_3)_2CO$	3	1	1	2		2^a	1	2	0	1
Methyl Acrylate (Inhibited) $CH_2{:}CHCOOCH_3$	3	3	2	3	2	2	2	2	0	3
Methyl Alcohol CH_3OH	3	1	1	2	1	1	1	2	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Methyl Amyl Acetate,iso $(CH_3)_2CH(CH_2)_3OOCCH_3$	2	2	1	1	1	1^a	2	1	0	0
Methyl Amyl Alcohol $CH_3CHOHCH_2CHCH_3CH_3$	2	2	1	2	2	2	2	2	0	0
Methyl Bromide CH_3Br	1*	3	3	4	0	1^a	2	1	0	0
Methyl Butyraldehyde	3	1	2	1	1	3	3	2	0	1
Methyl Chloride CH_3Cl	4*	0	0	2	0	1	0	1	0	0
Methyl Chloromethyl Ether,Anhydrous $ClCH_2OCH_3$	3	3	3	3	2	2	2	3	3	0
Methyl Cyclopentane  $CH(CH_3)CH_2CH_2CH_2CH_2$	3	0	1	2	1	2^a	2	0	0	0
Methyl Dichlorosilane (Dichloromethyl silane) CH_3SiHCl_2	3	4	4	3	3	3	2	3	4	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Methylene Chloride CH_2Cl_2	1*	2	1	2	1	2	2	1	0	0
Methyl Ethyl Ketone $C_2H_5COCH_3$	3	1	1	2	2	1	1	2	0	0
2-Methyl, 5-ethyl Pyridine $\underbrace{NHCH(CH_3)CH_2CH_2CH(C_2H_5)CH_2}$	1*	2	2^d	2	2	2	3	3	0	0
Methyl Formal	3	1	1	1	1	2^a	1	2	0	0
Methyl Formate $HCOOCH_3$	4	3	1	1	1	3^a	1	1	0	0
Methyl Hydrazine CH_3NHNH_2	4	3	4	4	4		2	4	0	4
Methyl Isobutyl Ketone $CH_3COCH_2CH(CH_3)_2$	3	1	1	1	2	1	2	2	0	0
Methyl Isopropenyl Ketone (Inhibited) $CH_3CO(CH_3):CH_2$	3	3	2	3			2	3	0	3

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Methyl Methacrylate (Monomer-Inhibited) $CH_2{:}C(CH_3)COOCH_3$	3	3	2	3	2	2	2	2	0	3
2-Methyl Pentane (Isohexane) $CH_3(CH_2)_2CH(CH_3)_2$	3	0	0	1	1	1	1	0	0	0
alpha-Methyl Styrene, Cumeme(Mixture) $C_6H_5C(CH_3)=CH_2;C_6H_5CH(CH_3)_2$	2	1	2	1	1		2	3	0	2
Methyl Trichlorosilane CH_3SiCl_3	3	4	4	3	3	3	2	3	4	1
Methyl Vinyl Ketone, Inhibited $CH_2=CHC(O)CH_3$	3	4	4	4	4	2	3	3	0	3
Mineral Spirits No. 10 (hydrocarbons)	2	0	1	1	1	1[a]	2	0	0	0
Monochloroacetic Acid (MCA) $CH_2ClCOOH$ (chlorocetic acid)	1	4	4	4	3	2[ND]	3	4	2	0
Monochlorodifluo-omethane CHF_2Cl	0	0	0	1	0	0[a]	0	1	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Monoethanolamine $H_2NC_2H_4OH$	1*	2	2^d	2	2	1	2	3	0	0
Monoethylamine $CH_3CH_2NH_2$	4	3^c	2^c	3	3	3	3	2	3	0
Monofluorophosphoric Acid (Anh) H_2PO_3F	0	2	3	2			2	3	0	0
Monoisopropanolamine $H_2NCH_2CHOHCH_3$	1*	1	2^d	1	2	1^a	2	3	0	0
Monomethylamine CH_3NH_2	4	3	2	3	2		2	3	0	0
Morpholine C_4H_8ONH	3*	1	1	1	2	2^a	2	3	0	0
Naphthalene, Molten $C_{10}H_8$	1	2	1^c	2	1	3	3	1	0	0
Nickel Carbonyl $Ni(CO)_4$	3	4	4	4		3^a	1	4	0	4
Nicotine, Liquid $C_{10}H_{14}N_2$	1	1	1	4		3	4	3	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Nitric Acid (58-68%) HNO_3	0*	3	4	3	3	3	2	4	0	0
Nitric Acid (95%) WFNA fuming HNO_3	0*	4	4	3	3	3	2	4^1	0	0
Nitrobenzene $C_6H_5NO_2$	1	3	2	4	3^a	3^a	3	2	0	1
O-Nitroclorobenzene (ONCB) $ClC_6H_4NO_2$	1	1	1	3	3	2	4	3	0	1
Nitroethane (NE) $CH_3CH_2NO_2$	3*	2	1	1	2		2	1	0	4
Nitrogen Tetroxide N_2O_4	0	4	4	4	3		3	4	2	0
2-Nitropropane CH_3CHNO_2CH	3*	1	1	1	2	3^a	2	3^f	0	4^1
Nitrous Oxide N_2O	0	0	0	1	0	0	0	3^f	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS	-	Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Nonane C_9H_{20}	3	0	0	0	0	2^a	2	0	0	0
Nonene, Isomers $C_5C_{11}CH(CH_3)C_2H_5$	3	1	1	0	0	1^a	2	1	0	1
Nonyl Alcohol $C_9H_{19}OH$	1	0	0	0	1	3^a	2	2	0	0
Nonylphenol $C_6H_4(C_9H_{19})OH$	1	1	2	1	2	3	3	2	0	0
Nonyl Trichlorosilane $C_9H_{22}SiCl_3$	1	2	4	3	3	3	3	3	4	1
Octadecyl Trichlorosilane $C_{18}H_{37}SiCl_3$	1	2	4	3	3	3	3	3	4	1
Octyl Trichlorosilane $C_8H_{17}SiCl_3$	1	2	4	3	3	3	3	3	4	1
Oleum $H_2SO_4.SO_3$	0	4	4	3	2	3	2	4	3	0
Pentaborane (Stabilized) B_5H_9	4	2		4	4		2	4	2	4

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Pentadiene 1,3 (Piperylenes) $CH_3CH=CHCH=CH_2$ (crude)	3	1	1	1	0	1^a	1	2	0	2
n-Pentane $CH_3(CH_2)_3CH_3$	4	0	0	1	1	2	1	0	0	0
Pentane, iso $(CH_3)_2CHCH_2CH_3$	4	0	0	1	1	2	1	0	0	0
Pentasodium Salt of Diethylene Triamine Penta Acetic Acid (VERSENEX 80) 51% H_2O $C_{14}H_{18}O_{10}N_3Na_5$	0	0	1	0	0	2	1	0	0	0
Perchloroethylene $Cl_2C:CCl_2$	0	1	1	2	1	3	2	1	0	1
Petroleum Ether	4	1	0	1	0	1	1	0	0	0
Phenol C_6H_5OH	1	2	3	3	2	3	3	2	0	0
Phenyl Trichlorosilane $C_6H_5SiCl_3$	1	2	4	3	3	3^{ND}	3	3	4	1

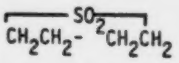
Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Phosphoric Acid (75-85%) H_3PO_4	0	0	3	1	2	3	2	3	0	0
Phosphorous Oxybromide (solid) POBr	0	1	4	4	3	3^{ND}	2	3	4	0
Phosphorus Oxychloride $POCl_3$	0	4	4	3	2	3^a	2	4	4	0
Phosphorous Trichloride PCl_3	0	4	4	4	2	3^a	2	4	4	0
Phosphorus, elemental, white P	3*	NA	4	4	3	4	1	4	0	0
Phthalic Anhydride (molten) $C_6H_4(CO)_2O$	1^b	2	3	1	2	2^a	2	3	1	0
Propane, Commercial C_3H_8	4	0	0	0	0	0	0	0	0	0
β-Propiolactone (BPL) OCH_2CH_2CO	1	3	3	3	3	2^a	1	2	0	1
Propionaldehyde C_2H_5CHO	3	2	1	2	2	2	2	2	0	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Propionic Acid $CH_3CH_2CO_2H$	2	2	3	2	2	2	2	2	0	0
Propionic Anhydride $(CH_3CH_2CO)_2O$	1	3	2	1	1	3^a	2	3	1	0
n-Propyl Acetate $C_3H_7OOCCH_3$	3	1	1	2	1	2^a	2	1	0	0
n-Propyl Alcohol $CH_3CH_2CH_2OH$	3	1	0	2	2	2	1	2	0	0
Propylene $CH_3CH:CH_2$	4	0	0	1	0	1^a	0	1	0	1
Propylene Glycol $CH_3CHOHCH_2OH$	1	0	0	0	0	1	1	2	0	0
Propylene Oxide OCH_2CHCH_3	4	3	2	2	2	1^a	1	3	1	3^e
n-Propyl Trichlorosilane $C_3H_7SiCl_3$	3	4	4	3	3	3	2	3	4	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Pyrosulfuryl Chloride $S_2O_5Cl_2$	0	3	1						4	
		(Patterson, A.M., Chemical Warfare Monographs (1919))						(Decomposes violently with water)		
Pyridine $CH<(CHCH)_2>N$	3*	2	2	1	2	2	3	3	0	0
Silicon Tetrachloride $SiCl_4$	0	4	4	4	4	2^{ND}	2	4	4	0
Sodium Chlorate Solution (42%) $NaClO_3$	0	0	1	1	1		0	4	0	0
Spirit of Nitroglycerine (alcohol solution (1 to 1.1%) of glycerol trinitrate	3	1	1	2	2	2	1	2	0	1
	In view of the low content of explosive, rating is based on alcohol solvent. If alcohol evaporates Col. I becomes 4.									
Stannic Chloride, anhydrous $SnCl_4$	0	3	3	2		2	2	3	3	0
Styrene Monomer $C_6H_5CH:CH_2$	3	2	2	2	1	3	2	2	0	3
Sulfolane  $CH_2CH_2-SO_2-CH_2CH_2$	1*	0	0	1	2	3^a	2	1	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Sulfur, Molten S	1-3*g	1	1^c	1	0	1	1	4^h	0	0
Sulfuric Acid (77-98%) H_2SO_4	0	2	4	2	2	3	2	4	3	0
Sulfur Dichloride SCl_2	0	4	3	4	3	2^a	2	4	2	0
Sulfur Monochloride S_2Cl_2	1	4	3	4	3	2^a	2	4		0
Sulfur Trioxide, stabilized $SO_3;(SO_3)_n$	0	4	4	3		3	2	4	4	0
Sulfuryl Chloride SO_2Cl_2	0	4	3	2		3^a	2	4	4	0
Tetraethyl Lead and Mixtures[†] $Pb(C_2H_5)_4$	$1^{\dagger}$	1	2	4	3	3	3	1	0	3
Tetraethylene Glycol $(C_4H_9OC_2H_4OC_2H_4)_2)$	1	0	0	0	0	1^a	1	2	0	0
Tetraethylene Pentamine $NH_2(CH_2CH_2NH)_3CH_2CH_2NH_2$	1	1^c	2^c	2	2	2	2	3	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Tetrahydronaphthalene $C_5H_2(CH_3)_2C_2H_4$	1	1	1	2	1	3	2	0	0	0
Tetrapropylene $(C_3H_6)_4$	2	1	1	1	0	1[a]	2	1	0	1
Tetrasodium Salt of Ethylene Diamine Tetra Acetic Acid (VERSENE 100) 53% H_2O $C_{10}H_{12}O_8N_2Na_4$	0	0	1	0	0	2	1	0	0	0
Thionyl Chloride $SOCl_2$	0	4	3	2		3[a]	2	4	4	0
Thio Phosphoryl Cloride $PSCl_3$	0	3	3	3			3	4	1	0
Titanium Tetrachloride (FM Smoke) $TiCl_4$	0	3	3	2	2	2	2	3	4	0
Toluene $C_6H_5CH_3$	3	1	1	2	1	3	2	1	0	0
Toluene Diisocyanate (TDI) (2,4-tolylene diisocyanate) $CH_3C_6H_3(NCO)_2$	1	3	3	4	2		4	3	3	3

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
1,2,4-Trichlorobenzene $C_6H_3Cl_3$	1*	1	1	2	1	3	2	1	0	0
1,1,1-Trichloroethane CH_3CCl_3 (Methyl Chloroform)	1*	1	1	2	1	3	2	1	0	0
Trichloroethylene $CHCl{:}CCl_2$	1*	1	1	2	1	2	2	1	0	1
Trichlorosilane $HSiCl_3$	4	4	4	3	3	3[ND]	2	3	4	1
Triethanolamine $(CH_2OHCH_2)_3N$	1*	0	1[d]	1	1	1	2	3	0	0
Triethylamine $(C_2H_5)_3N$	3	2[c]	2[c]	2	3	3	2	3	0	0
Tridecanol $CH_3(CH_2)_{11}CH_2OH$	1	0	0	0	0	0[a]	3	2	0	0
Triethyl Benzene $C_6H_3(C_2H_5)_3$	1	1	1	1	1	2[a]	2	1	0	0
Triethylene Glycol $(CH_2OCH_2CH_2OH)_2$	1	0	0	0	0	1	1	2	0	0

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Triethylene Tetramine $H_2NCH_2(CH_2NHCH_2)_2CH_2NH_2$	1*	2	2^d	1	1	1	3	3	0	0
Trimethyl Amine, aqueous solutions containing 25% amine by weight (TMA) $(CH_3)CH_3$	4	3	2	3	2	3	2	3	0	0
Trimethyl Chlorosilane $(CH_3)_3SiCl$	3	4	4	3	3	3	2	3	4	1
2,6,8-Trimethyl-4-nonanol $CH_3CH(CH_3)CH_2CHOHCH_2(CH_3)$. $CH_2CH(CH_3)CH_3$	1	1	1	0	1		2	2	0	0
Tripropylene C_9H_{18}(mixture of C_9 mono-olefins)	3	1	1	1	0	1^a	2	1	0	1
Tripropylene Glycol $HO(C_3H_6O)_2C_3H_6OH$	1	0	0	0	0	0	0	1	0	0
Turpentine $C_{10}H_{16}$	3	1	1	1	2	3	2	1	0	0
Valeraldehyde $CH_3(CH_2)_3CHO$	3	1	1	2	1	2	3	2	0	1

Ratings of Chemicals

Column:	I	II	III	IV	V	VI	VII	VIII	IX	X
	FIRE	HEALTH			WATER POLLUTION			REACTIVITY		
CHEMICALS		Vapor Irritant	Liquid Solid Irritant	Poisons	Human Toxicity	Aquatic Toxicity	Aesthetic Effect	Other Chemicals	Water	Self-Reaction
Vinyl Acetate $CH_3COOCH:CH_2$	3	1	1	2	2	1	2	2	0	3
Vinyl Chloride $CH_2:CHCl$	4*	2	1	2	0	0^a	0	2	0	2
Vinylidene Chloride (Inhibited)(VC) $CH_2:CCl_2$	3*	2	2	3	0	2^a	2	2	0	3
Vinyl Toluene (meta & para mixed) (Inhibited) $CH_2:CHC_6H_4CH_3$	2	2	1	1	1	3	2	2	0	3
Vinyl Trichlorosilane $CH_2CHSiCl_3$	3	4	4	3	3	3	3	3	4	3
Xylene $C_6H_4(CH_3)_2$	3	1	1	2	1	3	2	1	0	0
o-Xylene $C_6H_4(CH_3)_2$	3	1	1	2	1	3	2	1	0	0
p-Xylene $C_6H_4(CH_3)_2$	3	1	1	2	1	3	2	1	0	0

FOOTNOTES

* Denotes chemicals having a fire hazard unlike the hydrocarbons. Includes chemicals containing nitrogen, sulfur, or halogens which on combustion may evolve noxious gases; pyrophoric compounds; and those having exceptionally high or low ignition temperatures or narrow combustion limits.

a Denotes a chemical for which no published data of aquatic toxicity were found. Rating was estimated on the basis of physical properties and chemical similarity to other chemicals of known toxicity.

b Acetone cyanohydrin is stored under acidic conditions. Dilution or contamination with alkaline materials causes dissociation to acetone and toxic HCN.

c Column III ratings were based only on hazards from chemical burns and do not reflect hazards from contact with hot molten liquids or from cold refrigerated chemicals.

d The amines are only moderately irritating to the respiratory system and in contact with the skin. Thus, they are given intermediate rating in Columns II and III. Nevertheless in both liquid and gaseous form they are capable of causing eye injuries, and they must be handled with care to prevent eye contacts.

e The alkylene oxides, while capable of undergoing runaway polymerization under certain conditions, do not ordinarily require an added stabilizer. They are often blanketed with an inert gas to prevent the initiation of gas-phase decomposition.

f Nitrous oxide and nitropropane are normally unreactive, but may under certain conditions act as oxygen donors to react hazardously with other chemicals.

g Fire hazard of commercial sulfur varies considerably with organic content.

h Sulfur at 280°F does not react vigorously with Grade 1 through 3 substances on the present list of chemicals at this or at lower temperatures. It is gvien a 4 rating in Column VIII due to its ability to react with hydrogen-containing organic compounds to produce hydrogen sulfide.

i Concentrated nitric acid is a strong oxidizer and nitrating agent. Contamination with other chemicals must be carefully avoided.

j Nitropropane does not detonate from heat or shock, and is more stable than lower nitroalkanes. It may be capable of an explosion when heated under confinement.

k This material sublimes. If tanks vent into confined spaces, a coating of crystals will form in these spaces. This coating presents a flash fire hazard.

l Hydrogen peroxide is non-combustible and is given a 0 rating in Column I. In contact with other burning materials, however, 50% hydrogen peroxide may act as an oxygen donor to increase the severity of a fire. Accidentally mixing 50% hydrogen peroxide with other chemicals is highly hazardous, possibly leading to explosive mixtures.

m Toxic to rainbow fingerlings at 40 milligrams per liter.

n Toxic to blue gill at 138 milligrams per liter.

NA Sufficient data not available

ND No data

APPENDIX III

U.S. ENVIRONMENTAL PROTECTION AGENCY INCINERATION OF SPECIFIC MATERIALS

Reference: U.S. Environmental Protection Agency, Incineration in Hazardous Waste Management, EPA/530/SW-141, 1975.

APPENDIX III - INCINERATION OF SPECIFIC MATERIALS

The attached matrix lists hazardous waste stream constituents for which incineration is considered an acceptable waste treatment alternative and includes additional parameters of interest where known. It is obvious that a great deal of additional detailed information on suitable operating parameters is needed. Plans to develop needed information were previously summarized.

The material in these tables comes primarily from the TRW Systems, Inc., report entitled Recommended Methods of Reduction, Neutralization, Recovery and Disposal of Hazardous Waste, which was performed as an adjunct study conforming to the requirements of Section 212 of the Solid Waste Disposal Act of 1965 As Amended. Some additional material from OSWMP files was added where appropriate. Reference to these tables will provide the user with an indication of whether or not a material in question may be incinerated, and in many cases, some of the operating problems, parameters, and procedures involved. These tables should be used in making preliminary investigations to indicate the overall practicality of the incineration approach to a specific hazardous waste problem. In many cases, more detailed information can be obtained by referring to the TRW report or to the Hazardous Waste Management Division of the Office of Solid Waste Management Programs (OSWMP).

To simplify presentation, the available information has been condensed as follows:

Column 1-presents the volume number and page number in the TRW series in which the subject substance is discussed in more detail.

Column 2-check marks indicate whether incineration is considered acceptable for wastes of a concentrated and dilute nature. In most cases, where concentrated wastes are checked, but dilute wastes are not, the indication is that preferable, usually more economical approaches exist.

Columns 3-8-A cross mark indicates potential for formation of the pollutant. The type of heavy metal or additional pollutants of concern are indicated by chemical formula.

Column 9-where recycling or reclamation is a known alternative for at least some wastes containing the subject material, this column is checked. More information can be obtained from the previously mentioned TRW report.

Column 10-contains footnote numbers referring to additional criteria and information presented at the end of the table. This was done to preclude needless repetition of identical explanations.

In considering this information it must be remembered that most actual wastes are not only mixtures or solutions of the materials discussed here but also contain other materials, organic and/or inorganic. These may affect a decision on incineration and will affect the types and amounts of products of combustion to be in emissions and residues.

Although the Hazardous Waste Management Division of OSWMP believes, from current knowledge, that incineration is an acceptable treatment for the named materials, these tables should not be construed as an unqualified EPA endorsement, since detailed studies have not been performed with EPA monitoring to confirm the information. In the end, any decision regarding the environmental adequacy and safety aspects of incinerating a given waste material must depend on an overall analysis of the individual situation (incinerator characteristics, waste properties, etc.). Experimental or test burns may be desirable prior to full scale incineration to determine required operating parameters for complete destruction. Because of the health and environmental damage potential incineration of hazardous materials must not be entered into lightly. Reference is made to the list of considerations in Section I which should be addressed in analyzing any hazardous waste incineration proposal.

It is OSWMP's plan to update these tables on a periodic basis as more information is gathered. In this regard, users of this information can assist by notifying OSWMP of new information coming to their attention regarding test incineration results for various hazardous substances or waste materials.

FOOTNOTES

1. Controlled incineration of materials acceptable if equipped with a scrubber, catalytic or thermal unit to reduce NO_x, or SO_x emissions.

2. Incineration of concentrated materials and dilute organic mixtures is acceptable.

3. Incineration acceptable - preferably after mixing with another combustible fuel; care must be exercised to assure complete combustion to prevent the formation of phosgene. A scrubber is necessary to remove the halo acids produced.

4. It is believed that surplus military munitions, high explosives, and chemical warfare agents will be adequately destructed by the Armed Forces' Chemical Agent Munition Disposal Systems, which is nearing development completion. The main component of this system is a rotary kiln incinerator.

5. Concentrated waste containing no peroxides: discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides are extremely explosive. No enviornmentally satisfactory technique has yet been discovered for disposal; storage is dangerous. Interim approach involves perforation of a container of waste from a safe distance (using rifle or explosive) in the open, away from habitation; followed by open burning. Incinerate dilute wastes at 815°C (1500°F) minimum. Spray aqueous materials into hot incinerator.

6. Incineration at 1000°C (1800°F) for two seconds is believed adequate Alternately, primary conditions of 815°C (1500°F), one-half second and secondary conditions of 1200°C (2200°F), one second are considered equivalent.

7. Additional detailed criteria can be found in the TRW Systems report entitled Recommended Methods of Reduction, Neutralization, Recovery and Disposal of Hazardous Waste.

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Acetaldehyde	10 (1)	X								
Acetic Acid	10(21)	X								
Acetic anhydride	10(21)	X								
Acetone	10(1)	X							X	
Acetone cyanohydrin	10(41)	X				X			X	1
Acetonitrile	10(41)	X				X			X	1
Acetylene	10(55)	X	X						X	
Acetyl chloride	10(21)	X		X						3
Acridine	10(213)	X				X			X	1
Acrolein	8(51)	X	X							6
Acrylic acid	10(101)	X							X	
Acrylonitrile	10(41)	X	X			X			X	1
Adipic acid	10(101)	X							X	
Aldrin	5(1)	X	X	X						
Allyl alcohol	10(115)	X							X	
Allyl chloride	10(147)	X	X	X						

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Aminoethylethanol amine	10(155)	X	X			X			X	1
Ammonium picrate	7(69)	X	X							4, 7
Amyl acetate (Banana oil)	10(187)	X							X	
Amyl alcohol (Fusel oil)	10(115)	X							X	
Aniline (oil-amino benzene)	10(213)	X	X			X			X	1
Anthracene	10(55)	X								
Atrazine (2-chloro-4-ethylamino - 6-iso propylamine-S-triazine)	---	X	X			X				1,2,6
Benzene	10(55)	X								2
Benzene hexachloride (lindane)	5(29)	X	X	X						6
Benzene sulfonic acid	10(231)	X			X					1
Benzoyl peroxide	11(1)	X	X							7
Benzyl chloride	10(237)	X	X	X			Cl_2			6
Beryllium carbonate	12(243)	X	X				BeO_x	Be	X	
Beryllium chloride	12(243)	X	X	X			BeO_x	Be	X	
Beryllium hydroxide	12(243)	X	X				BeO_x	Be	X	

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Beryllium Selenate	12(243)	X	X				BeO_x SeO_x	Be Se	X	
Boron hydrides	7(21)	X	X				B_2O_3 H_3BO_3			7
Bromacil (5-bromo-3-sec-butyl-6-methyluracil)	--	X	X			X	HBr			1,2,6
Butadiene	10(55)	X							X	
Butane	10(55)	X							X	2
1,2,4-Butanetriol trinitrate	11(9)	X	X			X				1
Butanols Butyl alcohol	10(115)	X							X	
1-Butene	10(55)	X	X						X	2
Butyl acetate	10(187)	X							X	
Butyl acrylate	10(187)	X							X	
n-Butylamine	10(155)	X	X			X			X	1
Butylene	10(55)	X	X						X	2
Butyl mercaptan	10(263)	X	X		X		H_2S			1
Butyl phenol	10(245)	X								
Butyraldehyde	10(1)	X							X	
Camphor	10(1)	X							X	

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW VOl. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Carbolic acids (phenols)	10(245)	X								
Carbon disulfide	10(275)	X	X		X				X	1
Carbon monoxide	12(91)	X	X							
Carbon tetrachloride	10(283)	X	X	X			Cl_2		X	3
Chloral hydrate	10(283)	X	X	X					X	3
Chlorates with red phosphorus	13(5)	X	X	X						
Chlorobenzene	10(283)	X	X	X					X	
Chlordane	5(1)	X	X	X						2,3,6
Chlorine trifluoride and Chlorine pentafluoride	7(9)	X	X	X			HF Cl_2 F_2		X	3, 7
Chloroform - (trichloromethane)	10(283)	X	X	X					X	3
Chloropicrin	11(15)	X	X	X		X	Cl_2		X	1,3,6
Copper chlorotetrazole	7(83)	X	X	X		X	CuO_x	Cu		1
Creosote (coal tar)	10(55)	X								2
Cresol (cresylic acid)	10(245)	X								
Crotonaldehyde	10(1)	X							X	

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Cumene	10(55)	X							X	2
Cyanoacetic acid	10(41)	X				X			X	1
Cyclohexane	10(55)	X							X	2
Cyclohexanol	10(115)	X							X	
Cyclohexanone	10(1)	X							X	
Cyclohexylamine	10(155)	X				X			X	1
DDD	5(29)	X	X	X						6
DDT	5(29)	X	X	X						6
DNBP (alkanolamine salt of 4,6-dinitro-sec-butyl-phenol) (premerge)	—	X	X			X				1,6
Dalapon (sodium salt of 2,2-dichloropropionic acid)	—	X	X	X						2,6
Decyl alcohol	10(115)	X							X	
Demeton	5(73)	X	X	X	X		PO_x P			1,2,6
Diazodinitro-phenol	7(89)	X	X			X				1,4,7
Dicamba	—	X	X	X						2,6
O-Dichlorobenzene	10(283)	X	X	X						3

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Dichlorofluoromethane (Freon)	10(283)	X	X	X			Cl_2 HF			3
Dichloroethyl ether	10(283)	X	X	X						3
Dichloromethane (methylene chloride)	10(283)	X	X	X			Cl_2		X	3
2,4-D (Dichlorophenoxy acetic acid)	5(55)	X	X	X						2,6
1,2-Dichloropropane	10(283)	X	X	X					X	3
1,3-Dichloropropene (propylene dichloride)	10(283)	X	X	X					X	3
Dichlorotetrafluoroethane	10(283)	X	X	X			Cl_2 HF		X	3
Dicyclopentadiene	10(55)	X	X						X	2
Dieldrin	5(1)	X		X						1,2,6
Diethanolamine	10(155)	X				X			X	1
Diethylamine	10(155)	X				X			X	1
Diethylether	11(27)	X								5
Diethylstilbestrol	10(245)	X								
Diethylene glycol	10(115)	X							X	
Diethyltrimine	10(155)	X				X			X	1

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/$COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Diisobutylene	10(55)	X								
Diisobutyl ketone	10(1)	X							X	
Diisopropanolamine	10(155)	X	X			X			X	1
Dimethylamine	10(155)	X	X			X			X	1
Dimethyl sulfate (methyl sulfate)	8(59)		X		X					1,6
2,4-Dinitroaniline	10(213)	X	X			X			X	1
Dinitrobenzol (dinitrobenzene)	11(43)	X				X				1,6
Dinitro/cresols	5(101)	X	X			X				1,2,6
Dinitrophenol	11(51)	X	X			X				1,6
Dinitrotoluene (DNT)	7(97)	X	X			X				1,3,7
Dioxane (Diethylene oxide)	11(27)	X								5
Dioxin		X	X							2,6
Dipentaerythritol hexanitrate (DPEHN)	7(103)	X	X							4,7
Diphenylamine (phenylaniline)	11(63)	X	X			X				1
Dipropylene glycol	10(115)	X							X	
Diuron [3-(3,4-dichlorophenyl)-1, 1-dimethylurea]	---	X		X		X				1,6

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Dodecylbenzene	10(55)	X								2
Endrin	5(1)	X	X	X						2,6
Epichlorohydrin	10(283)	X		X					X	3
Ethane	10(55)	X	X						X	2
Ethanol	10(115)	X							X	
Ethanolamine (monoethanolamine)	10(155)	X				X			X	1
Ethyl acetate	10(187)	X							X	
Ethyl acrylate	10(187)	X							X	
Ethylamine	10(155)	X				X			X	1
Ethylbenzene	10(55)	X							X	2
Ethyl chloride	10(283)	X	X	X					X	3
Ethylene	10(55)	X	X						X	2
Ethylene bromide Ethylene dibromide	11(69)	X	X	X			HBr			
Ethylene cyanohydrin	10(41)	X	X			X			X	1
Ethylene diamine	10(155)	X	X			X			X	1
Ethylene dichloride	10(283)	X	X	X					X	3

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Ethylene glycol	10(115)	X								
Ethylene glycol nonoethyl ether	11(27)	X	X						X	5
Ethylenimine	11(91)		X			X				1
Ethyl mercaptan	10(263)	X			X		H_2S			1
Ethyl methyl ketone	10(1)	X							X	
Ethyl phenol	10(245)	X							X	
Ethyl phthalate	10(187)	X							X	
Fatty acids	10(101)	X							X	
Fluorine	8(25)	X	X				HF		X	1,7
Formaldehyde	10(21)	X							X	
Formic acid	10(101)	X								
Furfural alcohol	10(115)	X							X	
GB (Non-persistent nerve gas)	7(231)	X								1,7
Gelatinized nitrocellulose (PNC)	7(55)	X	X			X				1,4,7
Glycerine	10(115)	X								
Glycerolmonolacetate trinitrate (GLTN)	11(99)	X	X			X				1

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Glycol dinitrate (DDN)	7(111)	X	X			X				1,4,7
Gold fulminate	7(83)	X	X				AuO_x	Au		7
Guthion	5(73)	X	X		X		P PO_x			1,2,6, 7
n-Heptane	10(55)	X	X						X	2
1-Heptene	10(55)	X	X						X	2
Heptachlor	5(1)	X	X	X						2,3,6, 7
Herbicide orange (mixture of 2,4-D and 2,4,5-T)	---	X	X	X						2,3,6
Hexachlorobenzene (HCB)	---	X	X	X			Cl_2			2,3
Hexachlorophene	10(283)	X	X	X					X	3
Hexamethylene diamine	10(155)	X				X			X	1
Hexane	10(55)	X	X						X	2
Hydrazine (Anhydrous diamine)	12(327)	X	X			X	NH_3			1,7
Hydrazine oxide/ hydrazine	11(105)	X	X			X	NH_3			1
Hydrocyanic acid (aq.)	13(57)	X	X			X				1
Hydrogen cyanide	13(57)	X	X			X				1
Hydroquinone	11(111)	X							X	6

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Isobutyl acetate	10(187)	X							X	
Isopentane	10(55)	X							X	2
Isophorane	10(1)	X							X	
Isoprene	10(55)	X							X	2
Isopropyl acetate	10(187)	X							X	
Isopropyl amine	10(155)	X				X			X	1
Isopropyl ether	11(27)	X	X						X	5
Lead 2,4-dinitroresorcinate (LDNR)	7(137)	X	X			X	PbO_x	Pb		1,4,7
Lead styphnate (lead 2,4,6-trinitroresorcinate)	7(145)	X	X			X	PbO_x	Pb		1,4,7
Lewisite	7(247)	X	X	X			A_sO_3	A_s		3,7
Malathion	---	X	X		X		P PO_x			1,2,6
Maleic anhydride	11(119)	X							X	
Manganese methcyclopentadienyltricarbonyl	11(127)	X	X				M_nO_x	M_n		2,3,6, 7
Mannitol hexanitrate	7(155)	X	X			X				1,4,7
MCPA (2-methyl - 4-chlorophenoxyacetic acid)	---	X	X	X						2,3,6

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Mercury compounds (organic)	6(55)	X						Hg		
Mercuric fulminate	7(163)	X	X			X		Hg		1,4,7
Mesityl oxide	10(1)	X							X	
Methanol	10(115)	X							X	
Methyl acrylate	10(187)	X				X			X	1
Methylamine	10(155)	X				X			X	1
Methyl amyl alcohol	10(115)	X							X	
n-Methylaniline	10(213)	X				X			X	1
Methyl bromide	11(69)	X	X				HB_r			
Methyl chloride	11(69)	X	X	X						3
Methyl chloroformate	10(283)	X	X	X					X	3
Methyl formate	10(187)	X							X	
Methyl isobutyl ketone	10(1)	X							X	
Methyl mercaptan	10(263)	X	X		X		H_2S			1
Methyl methacrylate monomer	10(187)	X				X			X	1
Methyl parathion	5(73)	X	X		X		PO_x P			1,2,6

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/$COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Morpholine	10(155)	X				X			X	1
Naphtha (crude)	10(55)	X							X	2
Naphthalene	10(55)	X	X						X	2
β-Naphthalamine	10(213)	X				X			X	1
Nemagon (1,2-dibromo-3-chloropropane)	---	X	X	X			Cl_2 HBr Br_2			2,3,6
Nickel carbonyl	8(35)	X				X			X	1
Nitroaniline (meta,para-nitroaniline)	11(137)	X				X			X	1,6
Nitrobenzene	11(145)	X				X				1,6
Nitrocellulose	7(47)	X	X			X				1,4,7
Nitrochlorobenzene(meta or para)	11(153)	X	X	X		X				1,3,6
Nitroethane	11(161)	X	X			X			X	1
Nitrogen mustard	7(255)	X	X	X		X				1,3,7
Nitroglycerin	7(171)	X	X			X				1,4,7
Nitromethane	11(161)	X	X			X			X	1
Nitroparaffins	11(161)	X	X			X			X	1
4-Nitrophenol	11(173)	X				X				1

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Phthalic anhydride	10(21)	X								
Picloram	---	X	X	X		X	K KO_x			1,2,3,6
Picric acid	7(189)	X	X			X				1,4,7
Polychlorinated biphenyls (PCB's)	11(199)	X		X					X	
Polypropylene glycol methyl ester	11(27)	X	X						X	5
Polyvinyl chloride	10(283)	X	X	X					X	3
Polyvinyl nitrate	11(219)	X	X			X				1
Potassium dinitrobenzfuroxan (KDNBF)	7(197)	X	X			X	K KO_x			1,4,7
Potassium oxalate	12(145)	X	X				K KO_x			
Primers & Detonators	7(205)	X	X			X	PbO_x HgO_x	Pb Hg		1,4,7
Propane	10(55)	X	X						X	2
Propionaldehyde	10(1)	X							X	
Propionic acid	10(101)	X							X	
n-Propyl acetate	10(187)	X							X	
n-Propyl alcohol	10(115)	X							X	
n-Propylamine	10(155)	X				X			X	1

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
1 & 2 Nitropropane	11(161)	X	X			X			X	1
4-Nitrotoluene	11(173)	X				X				1
Nonyl phenol	10(245)	X							X	
Octyl alcohol (ethyl hexanol)	10(115)	X							X	
Oleic acid	10(21)	X							X	
Oxalic acid	11(183)	X	X							
Paraformaldehyde	10(1)	X				X			X	1
Paraquat	--	X	X	X	X					1,2,3,6
Parathion	--	X	X		X	X	PO_x			1,2,6
Pentaborane	7(21)	X	X				B_2O_3 B			7
Pentachlorophenol	8(67)	X		X			Cl_2			3
Pentaerythritol tetranitrate (PETN)	7(179)	X	X			X				1,4,7
n-Pentane	10(55)	X	X						X	2
Perchloroethylene	10(283)	X	X	X					X	3
Phenylhydrazine hydrochloride	10(213)	X	X	X		X			X	1,3
Phosphorus (white or yellow)	13(163)		X				P_4O_{10} P		X	

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	$HCL/COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Propylene	10(55)	X	X						X	2
Propylene glycol	10(115)	X							X	
Propylene oxide	11(27)	X	X						X	5
Pyridine	10(213)	X				X			X	1
Quinone	11(223)	X	X						X	6
Salicylic acid	10(101)	X							X	
Sevin	---	X	X			X				1,2,6
Silver azide	7(211)	X	X				AgO_x	Ag		4,7
Silver styphnate	7(83)	X	X				AgO_x	Ag		4,7
Silver tetrazene	7(83)	X	X				AgO_x	Ag		4,7
Smokeless gunpowder	7(119)	X	X			X				1,7
Sodium alloy	13(229)	X	X				Na NaOH Na_2O_3			
Sodium azide	13(237)	X	X			X	Na NaOH Na_2O_3		X	1
Sorbitol	10(115)	X							X	
Styrene	10(55)	X	X						X	2,7
Sulfur mustard	7(263)	X	X		X					1,7

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	$HCL/COCl_2$	SO_x	NO_x	Other	Heavy Metals		
2,4,5-T	---	X	X	X						2,3,6
Tricresyl phosphate	11(247)	X	X				P PO_x		X	
Triethanolamine	10(155)	X				X			X	1
Triethylene glycol	10(115)	X							X	
Triethylene tetromine	10(155)	X				X			X	1
Trifluralin	---	X	X			X	HF			1,2,6
Trimethylamine	10(155)	X				X			X	1
Tripropane(Norene)	10(55)	X	X						X	2
Turpeotine	10(55)	X	X						X	2
Urea (plus salts)	10(155)	X				X			X	1
Vernolate	---	X	X		X	X				1,2,6
Vinyl acetate	10(187)	X							X	
Vinyl chloride	10(283)	X		X					X	3
VX (persistent nerve gas)	7(231)	X	X		X	X	P PO_x			1,7
Xylene	10(55)	X	X						X	2
Xylenol (xylol)	10(245)	X							X	

INCINERATION OF SPECIFIC MATERIALS

Substance	TRW Vol. (page)	Conc. Criteria		Potential Combustion Products					Recycling Potential	Other Criteria
		Conc.	Dilute	HCL/ $COCl_2$	SO_x	NO_x	Other	Heavy Metals		
Zineb	---	X	X		X	X	ZnO	Zn		1,2,6

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